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COMPARATIVE MEASUREMENTS OF THE QUALITY OF ROENTGEN RAYS[1]

By JOHN J. BURBY, M.D., MADISON, WISCONSIN, and M. W. BARRY, M.D., OMAHA, NEBRASKA

IT is a generally accepted fact that the penetration or quality of roentgen rays can not be satisfactorily expressed by stating the tube potential, the tube current, and the filter, unless the potential has been measured by the spectrographic method. The "Committee on Standardization of X-ray Measurements" of your Society has adopted in its rules governing dosimetry, a paragraph which covers this well. A number of methods are named for defining quality, all of which have their advantages and disadvantages. A critical discussion of the various methods must keep in mind the particular requirements: they are entirely different for the physicist and the physician. The latter is interested only in simple ways and means to define the quality of the radiation which fixes all its characteristic properties of importance in the therapeutic application (Holthusen). We will illustrate this point later.

Since the introduction of the interrupterless or kenetron[2] type of apparatus in this country, relatively few data have been published permitting a comparison of the output of this new type and the still widely used mechanical rectifier machine (1). We felt that here was a definite gap to fill, and in this article results of measurements are reported, carried out on two machines of each type.

DESCRIPTION OF APPARATUS

The method of choice for measuring the quality of roentgen rays is undoubtedly the ionization method. We used three instruments, two having a large chamber guaranteeing independence of the wave length within the range of the spectra examined, and one with a thimble ionization chamber of low atomic material. All instruments were checked by radium, although such checks are not as essential in quality measurements as in quantity measurements. The entire set of readings was taken on each of the three instruments for each condition of radiation. Arrangements were made so that two instruments could always be placed in the same beam at one time. Saturation was checked as well as the leakage. The Kuestner instrument[3] did not show any per-

[1] From the Department of Roentgenology, University of Michigan, Ann Arbor, Michigan, and the Department of Radiology and Physical Therapy, University of Wisconsin, Madison, Wisconsin.

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[2] The word "kenetron" as used in this article refers to the hot cathode valve tube.

[3] A detailed description is found in *Strahlentherapie*, 1927, XXIV, 501.

ceptible leakage in 15 minutes, the electroscope[4] discharged over one-fifth of the scale in 21 minutes, while the Wulf ionometer[4] dropped over one-tenth of its scale in 14 minutes. These readings were taken on one of the most humid days in July. Although all instruments are reasonably protected by lead, further protection was provided by using a lead plate 25 in. × 25 in., 1 cm. in thickness, with a hole of 1 cm. diameter in the center (See Fig. 1). The tube was either enclosed in a lead drum or placed behind a small opening in a 6-inch concrete wall covered by sheet lead 6 mm. in thickness. The filters were placed, whenever possible, close to the target. If they were close to the ionization instrument, a difference in the readings of about 3 per cent was observed. This is in agreement with Holthusen (2), who gives 3 to 5 per cent increase in ionization when using the Kuestner instrument and a radiation of short wave length. All filters were carefully calibrated, but, in spite of this, ionization measurements occasionally showed a difference in absorption for filters of supposedly equal thickness. A comparison of filters of different origin with the values stamped on them sometimes revealed differences as high as 10 per cent when checked by ionization (See Table I). Inasmuch as three sets of filters of different origin were used, this assured us of the comparability of the values obtained in the measurements. The figures of Table I indicate transmission in arbitrary

[4]For description of these instruments, see RADIOLOGY, 1928, X, 300.

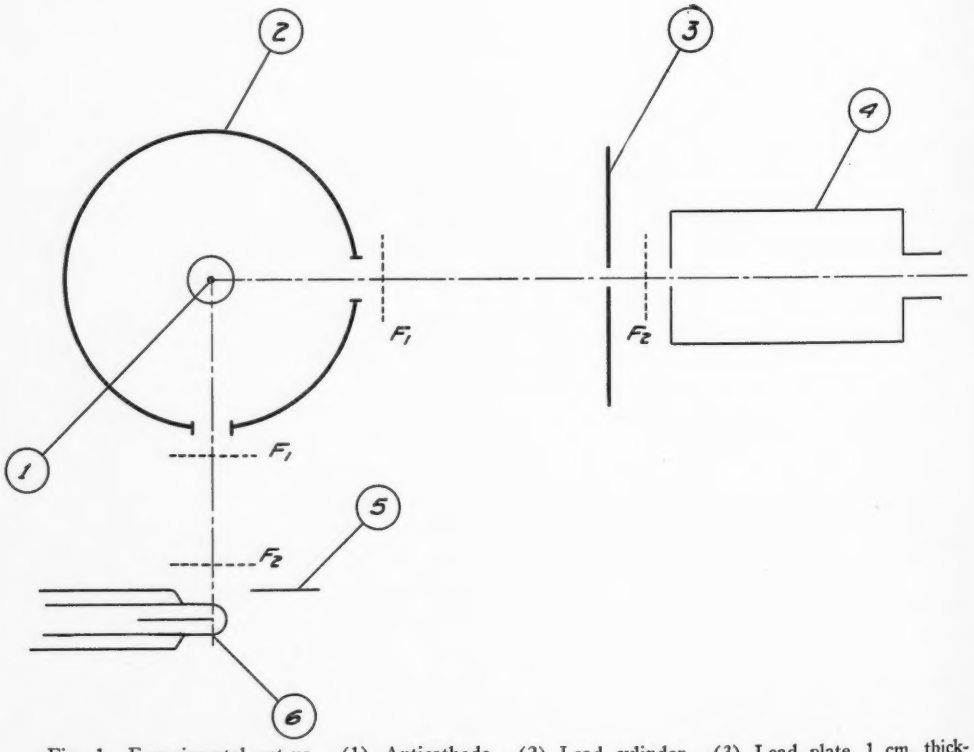

Fig. 1. Experimental set-up. (1) Anticathode. (2) Lead cylinder. (3) Lead plate, 1 cm. thickness. (4) Large ionization chamber. (5) Removable lead screen. (6) Thimble ionization chamber. (F_1 and F_2) Filter positions.

TABLE I

100 K.V., KENETRON APPARATUS, KUESTNER INSTRUMENT

Origin	Aluminum (in mm.)								Copper (in mm.)							
	.25	.50	1.0	1.0	1.0	1.0	5.0	10.0	0.5	.1	.1	.1	.1	.25	.50	1.0
Ann Arbor	8.4	8.8	12.7	12.7	—	—	9.0	21.1	9.5	13.9	14.0	13.6	13.5	14.1	22.6[5]	—
Madison	8.8	9.1	12.2	12.1	12.0	12.3	9.0	19.6	10.1	14.3	13.8	13.7	14.2	13.1	31.1	87.0
Kuestner	—	9.3	12.7	13.2	12.7	12.9	9.2	20.6	10.4	13.6	13.4	—	—	12.8	29.9	89.3

[5]The thickness of this filter was only 0.44 mm.

units. Before starting each series of readings, a lead plate of 1 cm. thickness was placed in the path of the rays. If no leakage resulted in the instrument, we were satisfied that no ionization current was recorded other than that due to the ionization of the air within the chamber. This is particularly important in the case of the thimble chamber, where the entire chamber has to be in the path of the radiation. An arrangement similar to that suggested by Grossmann (3) served the purpose very well. For the other two instruments which had large ionization chambers, a very thin pencil of rays was carefully screened out.

The potential was set by a kilovolt meter placed as usual in the primary circuit. Each time we checked the potential at the tube terminals by means of a Seemann spectrograph. All spectra were interpreted by using the scales furnished by Seemann and also with a micrometer device, as suggested by Glocker (4). The fluctuations of the line voltage were negligible, because all measurements were made after seven o'clock in the evening. Checks by a recording wattmeter in the primary circuit demonstrated this to our satisfaction.

From 60 to 90 K.V., inclusive, absorption curves in aluminum only were taken because of the difficulties involved in handling such thin layers of copper required within this range. For higher potentials, both aluminum and copper curves were plotted. In each instance, the absorption curves were drawn, based on data gained from the three ionization instruments. The half value layer in copper, aluminum, and the effective wave length in copper or aluminum are easily derived. Because Duane's charts did not permit us to read an effective wave length longer than 0.4 Å for aluminum and 0.24 Å for copper, we decided to record, in such cases, the percentage of transmission for either 4 mm. aluminum or 1 mm. copper. Anyone familiar with the method can interpret this percentage of transmission and repeat the measurements. It is surely more accurate to give experimental data as they are than to extrapolate or to calculate the effective wave length.[6] No photographic determinations, as suggested by Meyer (5), were carried out. We feel that Pohle and Barnes (6) have clearly shown the limitations of this method,

[6]Since then Duane and his co-workers have published charts (*Am. Jour. Roentgenol. and Rad. Ther.*, 1928, XX, 241) which permit the determination of lambda effective down to 2.2 A.

TABLE II

200 K.V. 25 ma.

Filter	Percentage of transmission		
	W.I. below	W.I. on side	K. on side
.5 Al.	100%	100%	100%
1.0 Cu. + .5 Al.	18.9%	19.3%	18.7%
2.0 Cu. + .5 Al.	9.7%	10.4%	10.1%

TABLE III

K.V.	Filter mm. Al.	H.V.L. (Al.)			Lambda eff. (Al.)		
		P. and B.	M.R.	K.	P. and B.	M.R.	K.
60	0.	.4	.4	.3	7.4 %	7.1 %	6.3 %
	1.	1.1	1.2	1.2	18.0 %	18.0 %	17.0 %
	2.	1.8	1.6	1.6	24.3 %	21.6 %	23.6 %
	3.	2.1	2.0	2.0	25.6 %	22.0 %	26.6 %
	4.	2.1	2.2	2.2	26. %	28.2 %	31.8 %
70	0.	.6	.5	.4	10.2 %	9.2 %	6.7 %
	1.	1.2	1.2	1.2	18.6 %	20.2 %	18.9 %
	2.	1.8	1.7	1.6	26.8 %	25.8 %	26.0 %
	3.	2.1	2.1	2.0	30.0 %	31.8 %	31.0 %
	4.	2.6	2.6	2.6	.4 Å	.38 Å	.376 Å
80	0.	.6	.5	.5	13. %	11. %	6.9 %
	1.	1.6	1.6	1.2	26. %	23.4 %	17.2 %
	2.	2.1	2.0	1.6	.4 Å	.4 Å	28.8 %
	3.	2.6	2.6	2.2	.38 Å	.38 Å	.38 Å
	4.	2.8	3.0	2.6	.38 Å	.37 Å	.358 Å
90	0.	.7	.6	.4	15. %	12.5 %	9.2 %
	1.	1.8	1.6	1.4	29. %	25.8 %	23.0 %
	2.	2.7	2.4	1.9	.38 Å	.39 Å	.4 Å
	3.	3.0	2.8	2.6	.37 Å	.37 Å	.36 Å
	4.	3.0	3.0	3.2	.37 Å	.36 Å	.34 Å

and Meyer himself (7) now prefers the ionization method.

EXPERIMENTAL RESULTS

For potentials over 150 K.V., the tube was enclosed in a lead drum which had two openings for the emission of radiation, one for a horizontal and one for a perpendicular beam. The construction of our ionization instrument made it necessary to use both directions; in order to satisfy us that the quality of both beams was alike, a series of readings were carried out, the results of which are presented in Table II. It shows that no appreciable difference between the penetration of horizontal and perpendicular beams of roentgen rays exists.

The end-results of all measurements based on approximately 3,000 electrometer readings[7] are compiled in Tables III and IV: the first column of values in each table is reprinted from the paper by Pohle and Barnes (6); the second column gives our own figures obtained on the apparatus with mechanical rectifier, and the last column represents those of the valve tube equipment. We conclude from these tables that the quality of radiation as delivered by the two types of apparatus under identical operating conditions does not vary considerably except in

[7]We wish to thank Dr. R. F. Sommer and Mr. W. D. Thayer for their valuable assistance in carrying out these measurements.

TABLE V

HOMOGENEITY FILTER

K.V.	Mech. Rect.	Kenetron
70	3.0 Al.	2.0 Al.
80	3.0 Al.	3.0 Al.
90	4.0 Al.	3.0 Al.
100	4.0 Al.	4.0 Al.
130	.25 Cu.	.25 Cu.
150	.5 Cu.	.4 Cu.
200	1.0 Cu.	.6 Cu.

TABLE IV

K.V.	Filter	H.V.L. (Al.)			H.V.L. (Cu.)			Lambda eff. (Al.)			Lambda eff. (Cu.)			
		P. and B.	M.R.	K.	P. and B.	M.R.	K.	P. and B.	M.R.	K.	P. and B.	M.R.		K.
100	0. Al.	0.9	0.8	.5	.025	.02	.02	18. %	15. %	10.5 %[10]				.3 Å.[9]
	1.0	2.0	1.8	1.4		.055	.06	.4 Å.	.4 Å.	24.8 %		2.9[8] %	.35 Å.	.375 Å.
	2.0	2.8	2.6	2.0		.08	.08	.36 Å.	.37 Å.	.4 Å.		3.7 %	.32 Å.	.34 Å.
	3.0	3.6	3.2	2.6		.12	.10	.34 Å.	.35 Å.	.37 Å.		5.7 %	.31 Å.	.33 Å.
	4.0	4.0	3.7	3.2		.15	.12	.32 Å.	.34 Å.	.35 Å.		6.7 %	.30 Å.	.32 Å.
110	0. Al.	0.9	0.8	.7		.025	.02	19.5 %	17.8 %	16.6 %				.42 Å.
	1.0	2.0	1.9	2.0		.06	.07	.39 Å.	.4 Å.	.4 Å.		4.6 %	.38 Å.	.36 Å.
	2.0	3.2	2.6	3.0		.1	.11	.35 Å.	.37 Å.	.36 Å.		6.3 %	.33 Å.	.33 Å.
	3.0	3.7	3.4	3.9		.14	.12	.33 Å.	.34 Å.	.33 Å.	.24 Å.	6.7 %	.32 Å.	.32 Å.
	4.0	3.8	4.2	4.6		.16	.17	.33 Å.	.32 Å.	.32 Å.	.24 Å.	7.5 %	.31 Å.	.31 Å.
120	0. Al.	0.9	0.9	.6	.035	.032	.02	21. %	18.2 %	15.7 %			.4 Å.	.4 Å.
	1.0	2.4	2.0	2.0	.08	.09	.08	.39 Å.	.39 Å.	.38 Å.		6.6 %	.34 Å.	.34 Å.
	2.0	3.0	3.0	3.6	.12	.14	.12	.34 Å.	.35 Å.	.336 Å.		8.0 %	.33 Å.	.32 Å.
	3.0	3.8	4.0	4.2	.16	.18	.16	.33 Å.	.32 Å.	.32 Å.	.24 Å.	.24 Å.	.32 Å.	.31 Å.
	4.0	4.2	4.8	5.0	.22	.21	.20	.31 Å.	.30 Å.	.296 Å.	.24 Å.	.23 Å.	.29 Å.	.29 Å.
130	0. Al.	1.4	1.0	.8	.04	.04	.025	25. %	21.8 %	18.5 %		4.6 %	.37 Å.	.38 Å.
	1.0	2.5	2.4	2.0	.08	.09	.10	.37 Å.	.38 Å.	.38 Å.		.24 Å.	.32 Å.	.32 Å.
	2.0	3.3	3.2	3.8	.15	.15	.14	.33 Å.	.35 Å.	.336 Å.	.24 Å.	.236 Å.	.3 Å.	.30 Å.
	3.0	4.5	4.3	5.0	.17	.19	.20	.32 Å.	.32 Å.	.296 Å.	.24 Å.	.226 Å.	.275 Å.	.28 Å.
	4.0	5.0	4.8	5.8	.21	.22	.23	.30 Å.	.30 Å.	.28 Å.	.23 Å.	.22 Å.	.27 Å.	.27 Å.
	0.25 Cu.	10.0	8.0		.47	.40	.32	.22 Å.	.23 Å.	.24 Å.	.19 Å.	.21 Å.		.21 Å.[8]
150	0. Al.	1.3	1.2	1.0	.06	.05	.04	27.8 %	25.3 %	26.0 %	7.7 %	7.1 %	.36 Å.	.35 Å.
	1.0	3.4	3.0	3.6	.13	.12	.13	.34 Å.	.35 Å.	.33 Å.	.23 Å.	.23 Å.	.3 Å.	.3 Å.
	2.0	4.4	4.2	5.6	.16	.17	.21	.32 Å.	.32 Å.	.31 Å.	.22 Å.	.226 Å.	.28 Å.	.27 Å.
	3.0	5.4	5.0	6.4	.20	.21	.26	.29 Å.	.3 Å.	.28 Å.	.21 Å.	.22 Å.	.27 Å.	.26 Å.
	4.0	5.9	6.0	6.6	.25	.25	.33	.27 Å.	.28 Å.	.26 Å.	.20 Å.	.21 Å.	.27 Å.	.25 Å.
	0.25 Cu.	11.0	9.0	10.1	.6	.45	.44	.18 Å.	.23 Å.	.22 Å.	.17 Å.	.19 Å.	.22 Å.	.19 Å.
	0.50	12.0	10.8	13.0	.8	.66	.60	.156 Å.	.16 Å.	.17 Å.	.164 Å.	.176 Å.	.18 Å.	.18 Å.
200	0. Cu.	4.3	4.0		.14	.16	.06				.22 Å.	.216 Å.		.325 Å.[8]
	0.25					.59	.87					.17 Å.		.156 Å.
	0.50	17.0	14.0	16.0	.92	.86	1.3				.16 Å.	.156 Å.		.14 Å.
	0.75						1.35							.138 Å.
	1.0	19.0	15.0	19.0	1.3	1.28	1.4				.138 Å.	.14 Å.		.13 Å.

[8]Transmission through 1.0 Cu.
[9]Transmission through .25 Cu.
[10]Transmission through 4.0 Al.

the range of high potential, where the valve tube machine produces radiation of higher penetration. From our absorption curves, it is also evident that the homogeneity filter for the valve tube apparatus is thinner than that for the mechanically rectified equipment (See Table V). Again we must say that this manifests itself more at potentials above 150 K.V. Figure 2 may serve as an example.

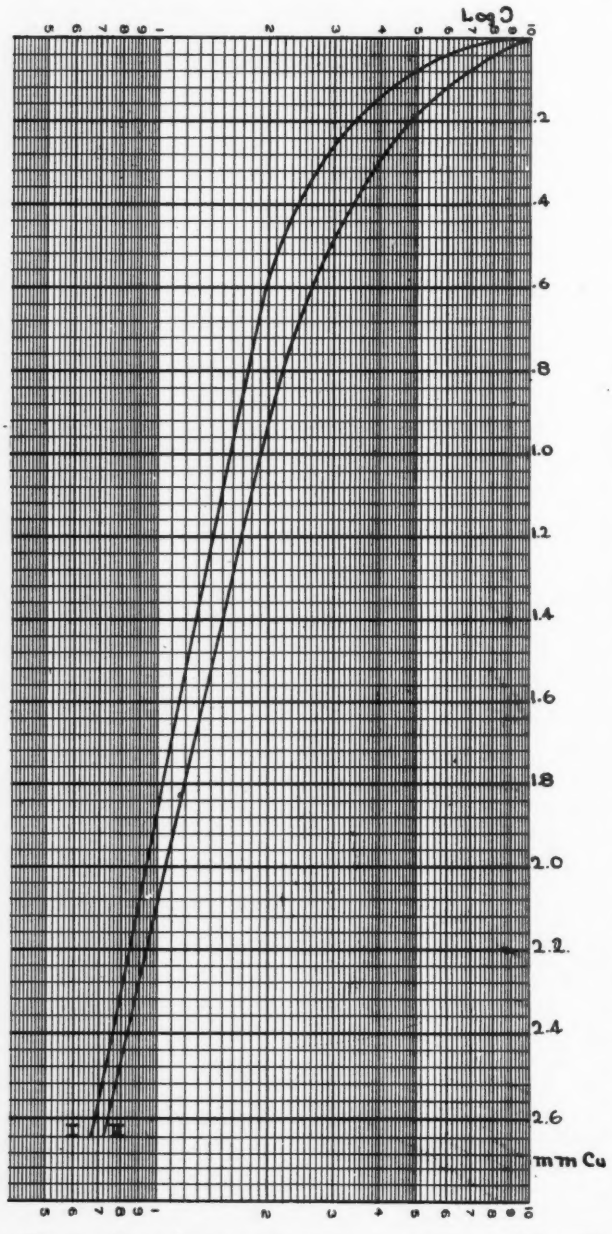

Fig. 2. Absorption curve in copper for equal potentials. (I) Kenetron unit. (II) Mechanical rectifier machine.

At this point, we wish to draw attention to the fact that the values for the effective wave length vary comparatively little for lower potentials and aluminum filtration. This is due to the translation of the percentage of transmission into terms of wave length, as indicated in Duane's charts, one of which we reprint here (Fig. 3). This can not be avoided. As demonstrated in Table VI, a definite increase in the percentage of transmission is less characteristic when stated in terms of effective wave length. Anyone familiar with these charts and the method of measuring will accept this as self-evident. However, we must assume that it is not generally understood (8).

As far as the reproduction of such measurements in practice is concerned, we refer to Table VII. These tests have been carried out by different observers on different days with different machines and different ionization instruments. This combination of changes in measuring conditions may lead to variations up to plus or minus 10 per cent. There is no doubt but that under ideal conditions the accuracy can be brought to a higher standard. However, in the roentgen laboratory where

TABLE VI

K.V.	Filter	Percentage transmission through 4.0 Al.	Lambda eff. in Al.	Percentage transmission through 1.0 Cu.	Lambda eff. in Cu.
100	0 Al.	15.0	—	—	—
	1 "	30.3	.4	2.9	—
	2 "	38.2	.37	3.7	—
	3 "	43.0	.35	5.9	—
	4 "	44.5	.344	6.7	—
150	0 Al.	25.3	—	7.1	—
	1 "	43.0	.35	11.6	.236
	2 "	50.0	.32	14.9	.226
	3 "	55.7	.3	17.5	.22
	4 "	60.0	.28	19.8	.21
	.25 Cu.	70.1	.23	27.6	.19
	.50 Cu.	80.5	.16	36.0	.176

these tests are bound to be carried out as a secondary procedure, one can not expect nor would it be reasonable to demand the precision of a physical laboratory. Of course, we do not want to be quoted as advocating inexact measurements; they should be done as exactly as possible and surely the fundamental errors must be avoided. Otherwise, it would be better not to attempt a calibration at all.

We also compared the intensity delivered by the two types of apparatus; the results are presented in Tables VIII, IX, and X. The latter table gives a ratio of $1 \div 3$ if based on equal quality of radiation; whereas if equal filter thickness is used, the ratio changes to $1 \div 2$ in favor of the kenetron apparatus.

TABLE VII

K.V.	Mm. Al.	I in % 7-10-28	I in % 7-24-28
80	0	100	100
	.25	66.5	64.7
	.5	49.5	50.4
	.75	41.5	41.5
	1	35.4	33.1
	2	21.5	18.7
	3	14.7	12.3
	4	10.7	9.0
	5	8.2	7.1
	6	6.6	5.2
	7	5.4	4.1
	8	4.6	3.5

SUMMARY

1. The quality of radiation produced by two types of X-ray apparatus has been studied; two different models of each type were available; three dosimeters, two with

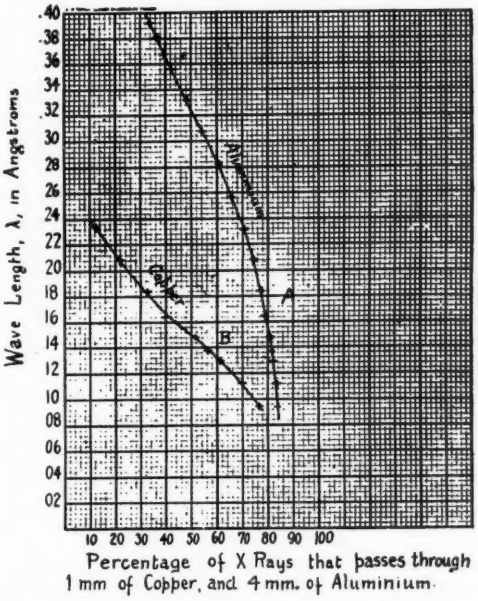

Fig. 3. Chart for effective wave length (Duane).

TABLE VIII

100 K.V., 5 ma., 30 cm.

Apparatus	0	Al.	2 Al.	3 Al.	4 Al.	
Mech. Rect.	1.3	.72	.48	.33	.27	*R* per second
Kenetron	2.0	.77	.51	.32	.29	

TABLE IX

Apparatus	50 cm.	.25 Cu.	.5 Cu.	.75 Cu.	1.0 Cu.	
Mech. Rect.	200 K.V., 25 ma.	1.07	.8	.66	.55	*R* per second
Kenetron	200 K.V., 4 ma.	.38	.27	.226	.172	

TABLE X

Output for equal quality λ eff. = .14 Å (through 1.0 mm. Cu.)

App.	50 cm.	Filter	Time in Milliampere-minutes for 500 *R*
Mech. Rect.	200 K.V., 25 ma.	1.0 Cu. + 1.0 Al.	380
Kenetron	200 K.V., 4 ma.	.5 Cu. + 1.0 Al.	123

large ionization chamber and one with a thimble chamber, served as measuring instruments.

2. The values obtained on the mechanical rectifier machine agree well with those reported by Pohle and Barnes. The penetration of the radiation produced by a kenetron apparatus does not differ markedly for potentials below 150 K.V. If higher potentials are used, there is a definite increase in the penetration as compared with the mechanical rectifier machines. The filter thickness required for obtaining homogeneous radiation is less for the kenetron apparatus.

3. The intensity of the radiation produced by the kenetron machine is higher if compared on the basis of equal quality of radiation, as well as for equal potential and filter thickness.

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THE QUALITY AVERAGE OF THE CONTINUOUS X-RAY SPECTRUM[1]

By A. MUTSCHELLER, PH.D., NEW YORK

THE exact definition and determination of the quality of X-rays is generally admitted to be of greater importance than quantity measurements, although the latter are by no means unimportant in the estimation and definition of X-ray doses. But then, a study of the meaning of absorption coefficients and their influence upon depth doses, affirms fully that understanding.

Radiation quality, as it is referred to in this article, is a term corresponding to the wave lengths, as they are usually given in tables for narrow portions of a spectrum and the wave length is generally given as a definition of the absorption coefficient of that particular part of the spectrum. In a continuous spectrum, however, such as we have to deal with in the complete X-ray beam, radiation quality is determined in various ways and nearly all of these methods represent an average of the penetrative qualities of all the useful wave lengths averaged over the various parts of the entire spectrum. The various methods employed for their determination, however, are subject to serious errors.

Thus, the determination of the minimum wave length is actually the most reliable method of estimating the highest voltage applied to the electrodes of the X-ray tube. But, so long as transient voltage waves are employed for exciting X-ray tubes, *i.e.*, mechanical interrupters of various types and construction, there is no direct or fixed relation between the minimum wave length and the wave length of the peak of maximum intensity. Therefore, unless uniform voltage current is always employed, the minimum wave length is not in any way a satisfactory definition of the radiation quality.

Measuring voltages of the secondary current with spark gaps is proven to yield errors up to 40 per cent in voltage readings and up to nearly 100 per cent in depth doses (1). The presence or absence of oscillations determines the difference between the voltage measured with a sphere gap and the actual useful voltage applied to the electrodes of the X-ray tube. Usually, the minimum wave length which depends accurately upon the highest voltage applied to the electrodes of the tube is lower than the sphere gap voltage measured in proportion to high frequency currents present in the secondary circuit.[2]

The half value layer method, which regrettably is so much employed and advocated, can also not be received with much enthusiasm, for absorption curves clearly demonstrate, on the one hand, that voltages from 150,000 on up usually give the same half value layer, and, on the other hand, by adjusting the rectifier, it is possible to produce half value layers corresponding to from 30,000 to 140,000 volts. Figures 1 and 2 are actual absorption curves and they clearly demonstrate this. Figure 1 is of two radiations which produce the same depth dose but which have half value layers differing by 60 per cent. In Figure 2, two absorption curves of radiations are given with the same half value layer, differing, however, by 16 per cent in depth dose.

The methods of determining the effective and the average wave lengths probably

[1]Read at the Fourteenth Annual Meeting of the Radiological Society of North America, in Chicago, December 7, 1928.

[2]This source of errors has been still further investigated and a detailed report is being prepared for publication.

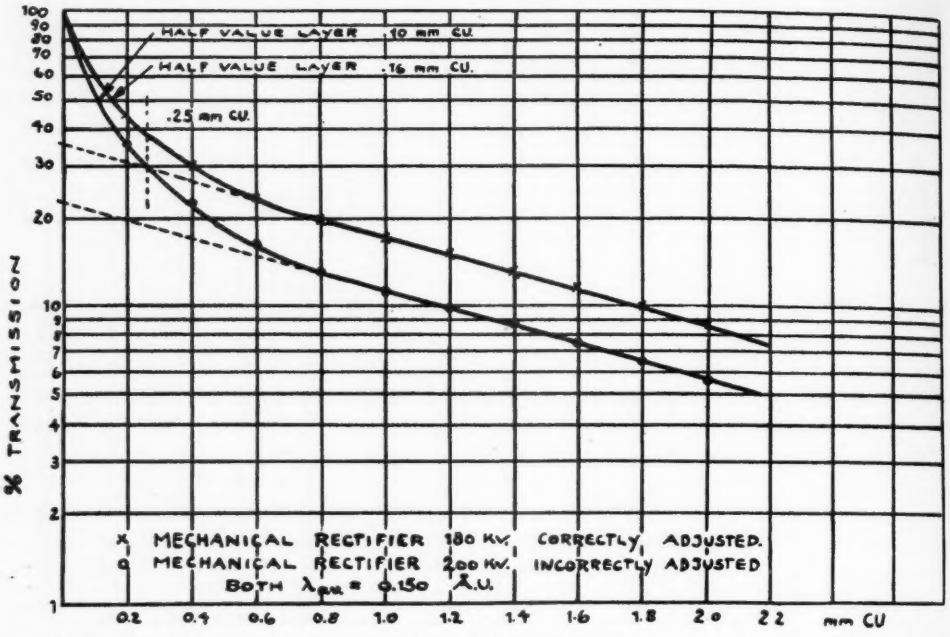
HALF VALUE LAYER .10 mm CU.
HALF VALUE LAYER .16 mm CU.
.25 mm CU.
% TRANSMISSION
X MECHANICAL RECTIFIER 180 KV. CORRECTLY ADJUSTED.
O MECHANICAL RECTIFIER 200 KV. INCORRECTLY ADJUSTED
BOTH λ_{av} = 0.150 Å.U.
mm CU

Fig. 1. Absorption curves of two radiations which produce the same depth dose. The half value layer of one is 0.1 mm. of copper and of the other 0.16 mm. of copper.

have been developed independently and simultaneously and it is the purpose of this paper to point out differences between the two methods and to illustrate the practical significance of the meaning of average wave lengths and their relation to the radiation depth doses. There are interesting mathematical relations which lead to very useful results, but, due to lack of time, I shall reserve their publication for another opportunity.

The effective wave length (2) is determined by measuring the intensity of the beam as obtained from the X-ray tube and then by measuring it again after inserting into the path of the beam either 0.25 mm. of copper or 2 mm. of aluminum. The percentage of the radiation transmitted through these sheets of metal is then a measure of the effective wave length and its numerical value is read from curves.

The process of determining *the average wave length* (3) consists in making an absorption curve of the radiation through increasing thicknesses of the same metal that is employed as a filter. The reciprocal of the discharge time of a small beam ionization leakage condenser, the walls of which are not directly exposed, is then proportional to the percentage radiation transmitted through the filter. Plotting these values on semi-logarithmic paper for the greater thicknesses of the metal will give a straight line, when errors are not present. Two points are then read from the curve a certain distance apart and the quotient obtained, either by calculation or by reading from a table or curve, gives the average wave length.

The use of the same metal which is employed as a filter when making the absorption curve is of great importance for the simple reason that the spectrum is different for each metal, and it is correct to find that different average wave length values are obtained with various metals. So, for instance,

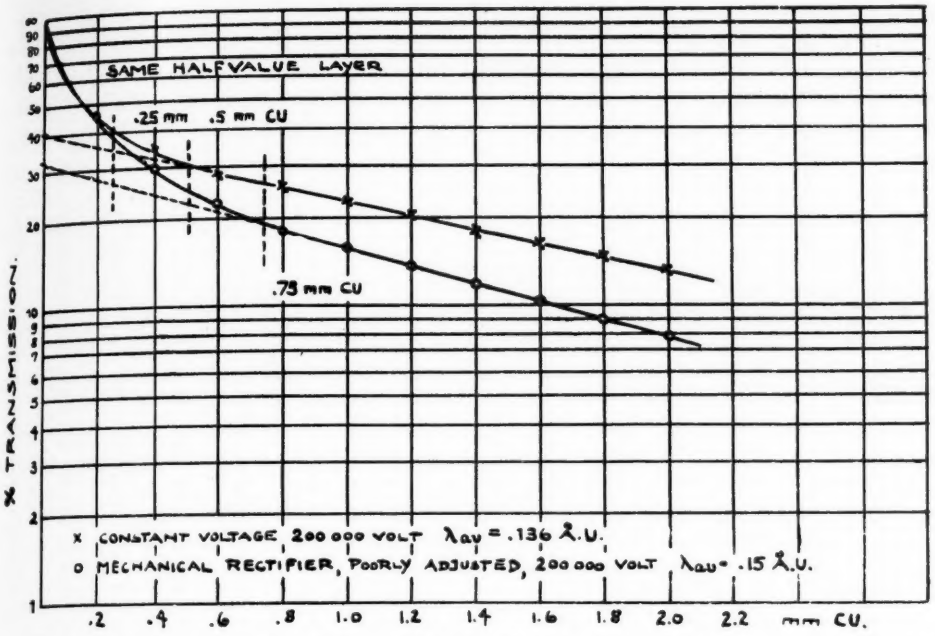
SAME HALFVALUE LAYER
.25 mm .5 mm CU
.75 mm CU
% TRANSMISSION
x CONSTANT VOLTAGE 200 000 VOLT λav = .136 Å.U.
o MECHANICAL RECTIFIER, POORLY ADJUSTED, 200 000 VOLT λav = .15 Å.U.
.2 .4 .6 .8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 mm CU.

Fig. 2. Absorption curves of radiations which have the same half value layer in copper but whose depth doses differ by 16 per cent.

Figure 3 shows absorption curves made in copper and aluminum of the same radiation, and it is interesting to point out that the average wave length measured through copper is 0.134 Å.U. against 0.150 Å.U. measured through aluminum.

Now, as to the method of determining the average wave length, it is necessary to remark not only that the part of the curve which is shown as a straight line and in which the absorption coefficient is constant, can be used for determining the average wave length, but also, any other point along the curve, even where it is bent and which points represent thinner filters, can be taken to determine the average wave length. For instance, on Figure 3 the average wave length is determined from the slope of a tangent drawn at the point corresponding to a filter of 1.84 mm. of aluminum. The average wave length at that point is 0.32 Å.U. and the depth dose measured there is 18 per cent. When the filter thickness is increased to 5 mm. of aluminum, the average wave length is changed to 0.15 Å.U. and the depth dose is increased to 27 per cent. If, however, a filter of ½ mm. of copper is employed, then the depth dose is 40 per cent in each case at 60 cms. distance with 10 cms. of water interposed. It would, therefore, seem that the average wave length values vary distinctly with changes in depth doses, and that the absorption curve lends itself to very useful interpretations which no other method for estimating the quality of a continuous X-ray beam can furnish.

The same conditions of tube excitation and of filters as those before mentioned are represented in Figure 4. The upper outline represents the spectrum as obtained with constant potential giving a minimum wave length corresponding to 180 K.V. applied to the electrodes of the X-ray tube. The effects of various filters are shown in the lower curves, which are marked according to the filter and its thickness. If we con-

sider the spectrum obtained when the filter is ½ mm. of copper, for instance, it is interesting to note that, in order to maintain the same maximum intensity, a filter of 1.84 mm. of aluminum must be used. Therefore, same as is obtained with 0.5 mm. of copper. Nevertheless, if we transpose this curve to the same maximum intensity as that obtained through ½ mm. of copper, then it shall be very similar to the 1.84 mm. curve,

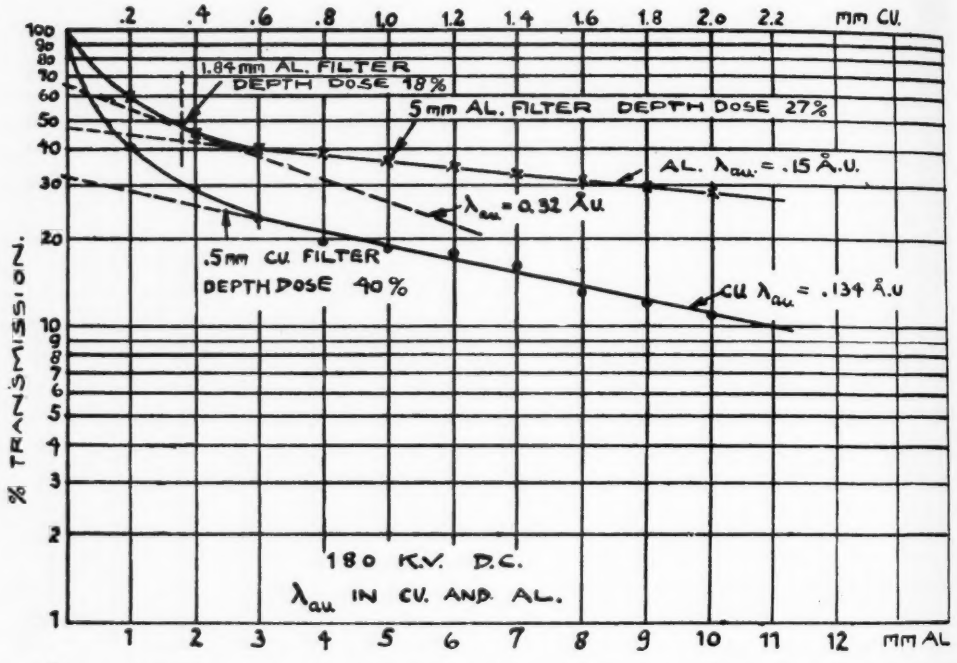
.2 .4 .6 .8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 mm CU.
1.84 mm AL. FILTER DEPTH DOSE 18%
5 mm AL. FILTER DEPTH DOSE 27%
AL. λau = .15 Å.U.
λau = 0.32 Å.U.
.5 mm CU. FILTER DEPTH DOSE 40%
CU λau = .134 Å.U
% TRANSMISSION.
180 K.V. D.C.
λau IN CU. AND AL.
1 2 3 4 5 6 7 8 9 10 11 12 mm AL

Fig. 3. Absorption curves in copper and aluminum of the same radiation, showing also average wave lengths for various filters and how the depth doses are influenced.

we can say that 1.84 mm. of aluminum decreases the useful maximum intensity to about the same extent as ½ mm. of copper. But we have further to note that the aluminum filter allows all the long wave length radiation represented by the area between the two curves to pass through, and the result is that while the depth dose obtained with the ½ mm. copper filter is 40 per cent, the depth dose obtained with the 1.84 mm. aluminum filter is just 18 per cent. If we then look at the radiation obtained through 5 mm. of aluminum, it would seem that, except for the difference in the intensity maximum, the spectrum would be nearly the this being indicated by the fact that the depth dose through 0.5 mm. of aluminum has been increased to only 27 per cent. The 10 mm. of aluminum, as shown by the lowest curve, does not effectively or materially improve the depth dose, and for that reason we again reach the definite conclusion that for this radiation, aluminum is not a filter tending to increase profitably the depth dose, but that copper—or possibly still heavier atomic metals—are much more effective in increasing the depth dose with respect to the surface intensity. Absorption curves and average wave lengths determined from them, as shown in Figure 3, give numerical

values which are to a very large extent proportional to the depth dose obtained, and they disclose the effects not only of various filter materials but of various filter thicknesses as well and it would appear justifiable to seek to establish, if possible, direct relationships between average wave lengths measured and depth doses or other useful factors.

Such a summary is presented in Figure 5. For various average wave lengths, as determined from absorption curves in copper and aluminum, there are shown the depth doses measured at 60 cms. through 10 cms. of water. These curves, therefore, show the percentage depth dose as it depends on the average wave length, measured through copper or aluminum. The curves, of course, show again clearly, as is generally well known, that the depth doses are not increased very substantially through thicker aluminum filters when higher voltages are applied to the tube. On the other hand, at lower voltages, aluminum is quite useful as a filter, principally for the reason that very thin copper filters, as would be required for low voltage radiations, are mechanically difficult to produce. Copper, on the other

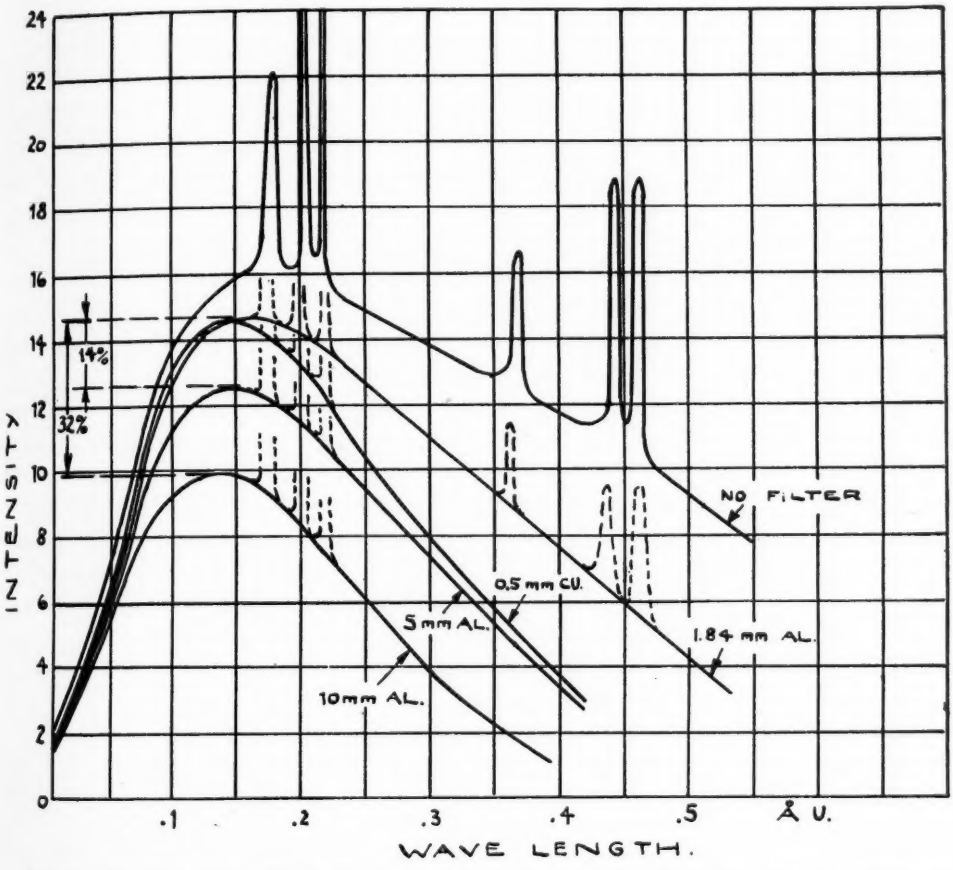

Fig. 4. Spectra filtered through various thicknesses of copper or aluminum. Figure 3 shows the absorption curves of these filtered radiations.

hand, gives very much better depth doses when used as a filter for higher voltage radiations and it is possible to predict at this moment that certain heavier atomic metals shall give even better depth doses so long as their characteristic absorption wave length does not introduce difficulties. Further study of this subject is necessary and in actual progress.

But a study of these curves cannot fail to impress one with the fact that while there is no direct fixed relation between the average wave length and the depth dose, there seems to be much greater similarity between the curve representing the logarithm of the ratio of the intensity transmitted against the original intensity. This suggests a definite mathematical relation and gives rise to the hope that it might be possible, by simple calculation from the average wave length or the logarithm of the two ratios which can be easily read directly from the absorption curve, to calculate the depth dose. This appears to be true both for copper and aluminum curves and again the indications are that if the average wave length is correctly determined, either in copper, aluminum or some other metal, the values obtained are in a definite relation with depth dose.

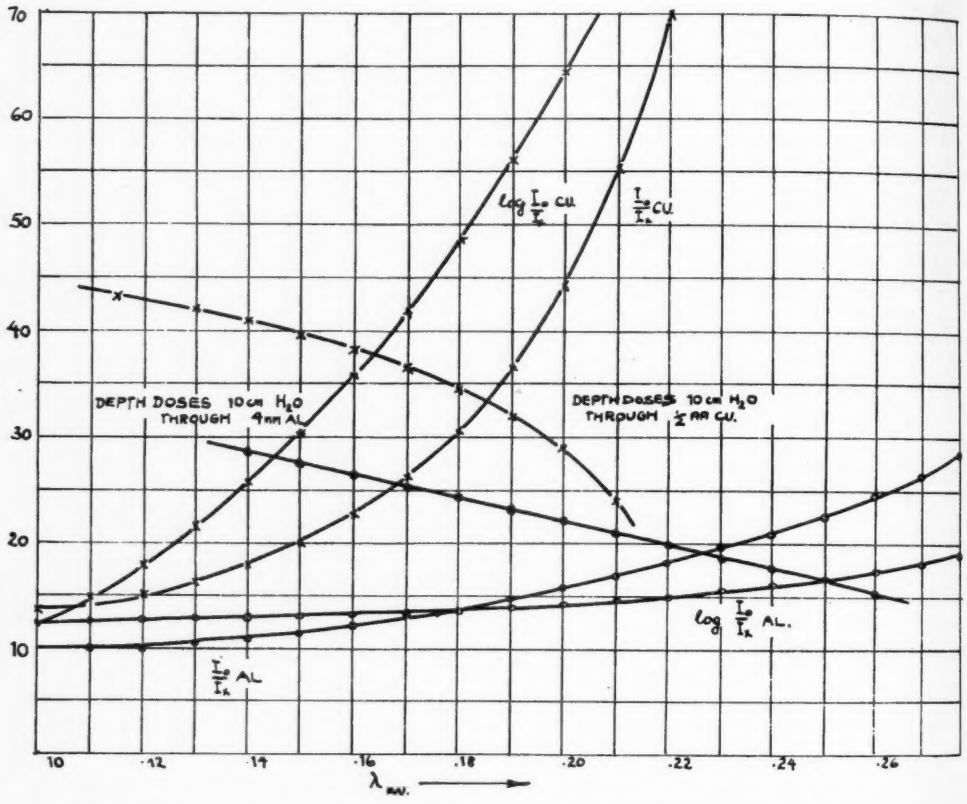

Fig. 5. Shows relations between average wave lengths, measured depth doses, and other data.

As a consequence of the foregoing, it should appear that it is utter fallacy to state

measurements of voltage or any other indirect measurement instead of making tests on the radiation itself. Statements of radiation quantity in terms of milliamperes are now no longer accepted as a description of the radiation intensity, and statements of secondary voltage are even less acceptable as an expression of the quality of the radiation. This is borne out by the fact that with actual measurements made on therapy apparatus of various types and constructions, it was possible to measure depth doses varying between alarmingly wide limits. This has been brought out before this Society repeatedly and needs no further proof. From the physical point of view, it could be testified that under the conditions of quality measurements employed in the past, it is impossible to expect any consistent or uniform clinical results. In fact, all disappointments and failures of X-ray therapeutic results are fully explainable and are unquestionably due to errors in the estimation of the quantity and, in particular, of the quality of the radiations employed. Continuation of the old technics would but still further discredit X-ray therapy and ultimately completely deprive the patient of the help which he can justly expect from it.

SUMMARY

By way of summary, the following advantages are on the side of average wave length determinations:

1. Increased accuracy, by excluding the errors possible when only two determinations are made—errors in the metal thickness, leakage of the instrument, or non-constant absorption coefficient.

2. The average wave length can be read for thinner filters along the part where the absorption curve is bent, and with values obtained, which are in definite relation to the depth doses.

3. From the point where the absorption curve becomes a straight line it indicates what minimum filter thickness will produce adequate filtration for best depth doses.

4. The absorption curve gives valuable information as to the adjustment of mechanical rectifiers, gassy condition of the X-ray tubes, or other errors which usually are not so easily detected.

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DISCUSSION OF PAPERS BY DR. BURBY AND DR. BARRY; DR. MUTSCHELLER.

LAURISTON S. TAYLOR (Bureau of Standards, Washington, D. C.): In regard to the paper by Dr. Mutscheller, one must recognize in it a commendable degree of originality and persistent study. It, also, at least presents a very simple picture of the radiation quality or energy distribution.

However, I am of the opinion—and others also agree—that from the physical point of view the designation of quality by means of the *average wave length* is not theoretically correct, though it may give a very close description, depending upon conditions. The essayist evidently starts with the expression $\frac{I}{I_0} = e^{-\mu x}$ where μ is the absorption coefficient of the medium for a given wave length of homogeneous radiation. Putting this in the form

$$\log \frac{I}{I_0} = -\mu x$$

he plots $\log \frac{I}{I_0}$ against χ the filter thickness. After a certain amount of filtration this relation becomes *nearly linear,* but never exactly so, since this would mean a

constant value for μ and correspondingly a monochromatic beam of radiation. This may approximate the truth but can never be exactly true.

In any accurate expression for the continuous X-ray spectrum, we must limit our discussions to conditions where there is no line radiation. Of course, this line radiation is present in all therapeutic work, so we must choose a method that expresses the quality correctly at least below the voltage where line radiation appears. This method can be found in either the effective wave length measurement or in the half value thickness determination. The latter is certainly theoretically correct and is obtained from just such a curve as Dr. Mutscheller's, except that it makes allowance for the slight curvature in the lower part of the curve. The energy between given wave lengths λ and $\lambda + d\lambda$ is a function of λ or $E_\lambda = \int (\lambda)$, so that the total spectral energy is given by $I_O = \int f(\lambda)\, d\lambda$. If, then, we place a copper filter in the beam $I_F = \int e^{-\mu\lambda\chi} f(\lambda) d\lambda = \int f(\lambda) e^{-(A\lambda^3 + \kappa)\chi} d\lambda$.

The expression for $E_\lambda = f(\lambda)$ has recently been evaluated by Kulenkampff. The dependence of μ on the wave length has been determined by Richtmyer, so that it is possible actually to calculate the energy distribution for any filtration. The half value layer is the thickness χ of the material (copper), which reduces the total energy of the beam I_{OF} to one-half. Thus the energy I_F after inserting the proper filtration is equal to $\frac{I_{OF}}{2}$ or $\frac{I_{OF}}{I_F} = 2$. Obviously the same ratio can be obtained in the equations for I above by inserting the proper values of λ and χ. Thus it is seen that the half value method is theoretically correct and makes proper allowance for the absorption coefficient.

To obtain the effective wave length described by Duane, a similar reasoning can be followed. Any correct method must make proper allowance for the absorption coefficient—a quantity which, under the conditions, is not constant.

Another question which I am very glad Dr. Mutscheller has brought up is that concerning the practical measurement of high voltages. In the hands of the less experienced they are all subject to error. The sphere gap method is reliable only where there is freedom from surges. Consequently, as surges are very frequent in improperly adjusted mechanical rectifiers, little dependence can be placed on ordinary measurements. The same applies to constant potential generators when proper devices to prevent surges are omitted. However, the latter lends itself to fairly accurate voltage measurement with the sphere gap in the following way:

The gap is narrowed until the first discharge takes place. This causes a somewhat heavy current drain, discharging the condensers considerably below their normal potential. After a certain time the condensers reach their normal potential and the gap again discharges. If, when timing the interval between discharges, they are found to be fairly regular, then the sphere gap reading gives a fairly accurate voltage measurement.

When obtaining the short wave length limit as a means of voltage measurement, care must be given to the technic. In the use of a small commercial spectrograph, scattering may produce a very misleading darkening below the cut-off. Surges may do the same, though usually to a lesser extent except in very poor equipment. Only when properly constructed and carefully used is the spectrograph dependable. The ionization spectrometer gives perhaps the best results, but it is not a practical instrument for the physician.

A voltage determination can also be made from measurements of the half value layer for radiation of a given filtration. Holthusen and Behnken have plotted a series of

curves for the half value layer at different voltages. Thus, by measuring the half value layer one can interpolate between the voltage curves and thus obtain a fairly good potential measurement. These curves differ but little between the various mechanical rectifying systems. There is a small difference between constant potential and mechanically rectified systems and no appreciable difference between different constant potential generators.

DR. G. FAILLA (New York): It must be rather perplexing to our medical friends to hear physicists, who are supposed to deal with an "exact science," more or less contradict one another. It should be noted, however, that in general such disagreements are due to different interpretations of experimental results which are not disputed. Since interpretations are subjective to a considerable extent, such differences are not surprising. But in the case under discussion there is a difference of opinion about the experimental results themselves.

Dr. Mutscheller gets a straight line for the copper absorption curve, beyond a certain filter, when plotted to a semi-logarithmic scale. As Dr. Taylor has just pointed out, this is really impossible, and therefore the straight line which Dr. Mutscheller reports must be due to some peculiarity in the experimental set-up employed. Beyond a certain filter the curve approaches a straight line, but is never straight (at least, within the limits reported by Dr. Mutscheller) because the radiation is not homogeneous.

As to the relative merits of "effective wave length" and "average wave length," I wish to point out that the two are intrinsically the same, and that, therefore, one is no better than the other. As a matter of fact, neither one is sufficient to specify the quality of radiation. For this purpose it is necessary to state also the type of X-ray machine employed, the voltage applied to the tube, and the filter.

DR. MUTSCHELLER (closing): I am very glad that all these points have been mentioned which seem to be stumbling blocks over which the idea of wave length definition has to develop. In the first place, I would like to explain how the term "average wave length" arose. It is not a radically different wave length, as Dr. Failla seems to think, but, the same as the effective wave length, is fundamentally based upon the well known definition of the absorption coefficient in the well known absorption equation. But the effective wave length is calculated from two points experimentally determined through which naturally an absorption curve can be drawn. It is, then, the slope or tilt of this curve which gives, as read from tables, a numerical value for the effective wave length.

To ascertain the average wave length a number of points are determined and only those are used which, when plotted on semi-logarithmic paper, lie along a straight line, from which the average wave length is determined. It can be either calculated from the slope of this line or its numerical value can be read from tables or a curve.

Previously, Professor Duane had suggested the use of two different metals, generally copper and aluminum, for the determination of the effective wave length, and inasmuch as the average wave length method avoids some of the errors of the two-metal method, I selected the name "average wave length," for, at that time and even now, there are rather important differences in the process of carrying out the two methods.

One point that seems to be puzzling and which is not very easily explained from the physical point of view is the fact that the absorption curves when plotted on semi-logarithmic paper or when their logarithms are plotted, come out a straight line. This is contrary to expectations from the theoretical point of view, for, as is well known, the

continuous spectrum changes with increasing filtration. The maximum intensity of the intensity curve with increasing filtration naturally shifts towards the short wave length end. However, we have to keep in mind that the characteristic lines play an important part and these do not shift with filtration. We have, therefore, two zones to deal with in a spectrum, one which does not change its wave length, therefore remaining stationary, and the other which does change wave lengths and therefore shifts with increasing filtration. Hence it is the regular change in the ratio of the two intensity maxima which determines the slope of the absorption curve, and, knowing that both these maxima change as the square with increasing or decreasing voltages, it would follow that in the first place the slope of the absorption curve should be a straight line and in the second place, it is explained why the absorption coefficient becomes constant, although ordinarily, when considering only the continuous spectrum, that would not be possible.

We, therefore, have to keep in mind that an absorption curve does not represent, let us say, instantaneous absorption coefficients of every particular wave length, but it represents an average, and by studying the question that way, I think, looking at the entire problem more from the collective point of view rather than from the particular point of view, one will be enabled to understand these particular characteristics and how a method of the average wave length is fundamentally based.

A short time ago I talked over this problem with Professor Duane and, as I understand him, he has no objection to any of these conclusions: in fact, I believe he admits that the absorption curve or the average wave length method has many direct advantages and is much more reliable than the effective wave length method.

Now, as to high voltage measurements, especially of uniform voltage current, it must be stated that there are now quite a number of methods, each leading to a different result. The spectrum curves which I have shown, it is true, have a peculiar notch at the minimum wave length end. That is perfectly true and the reason for this is that, in photographing, a spectrum can be forced. After a conversation with Professor Glocker I have made attempts to improve his method so as to make it more reliable. There is, in the hands of the Editor of RADIOLOGY, a paper in which I outlined a method showing how, with the aid of a microscope, the spectral intensity curve can be so photometered that that peculiar notch, which depends on developing, may be excluded. So far as I know, the method described in that paper furnishes accurate and fully reproducible results, from which all possibilities of the forcing of the end-result in the developing process of the spectrum are eliminated.

Then, I would like to say a word about the absorption curves which Dr. Burby has shown. As I recollect, he showed two absorption curves, one of a mechanical rectifier which showed higher relative intensities than one obtained with the constant potential apparatus. I believe that fact is puzzling Dr. Burby and his co-workers, but I feel that there is a satisfactory explanation for them.

In the first paper which I published on average wave lengths, I pointed out that if the intensity percentage transmitted through a certain filter for the radiation of a mechanical rectifier is divided into a constant, then there is a fairly dependable value obtained for the erythema dose time. For instance, when employing a mechanical rectifier and a standard deep therapy X-ray tube which does not contain any extensive tungsten deposit, one reads the percentage of transmission for the filter thicknesses employed, and if that value is divided into the

constant 6800, then, the result is the erythema dose time in minutes. But, repeating the same process with constant potential current, this same constant does not hold. It had to be increased, as I found, to about 9000. I believe Dr. Glasser independently found that the value of this constant is 9200. That means that the spectral distribution produced by constant potential is considerably different from that produced by mechanical rectifiers, which difference consists in this: that the constant potential apparatus produce a mixture of rays consisting of a very soft, easily absorbed radiation and then a fully and normally penetrating radiation which passes through the filter. Against this, we have in a mechanical rectifier a radiation, which, to use similar terms, consists of a portion of highly penetrating rays and a portion of medium penetrating rays. For that reason the wall of the X-ray tube is already an efficient filter for the very soft component of the constant potential radiation and usually a somewhat thinner additional filter is sufficient to give a constant absorption coefficient. The medium penetrating radiation of the mechanical rectifier is not very much affected by the glass wall of the tube but requires quite a substantial filter to make the absorption coefficient constant. This fact, I think, is clearly brought out by the two absorption curves as found by Dr. Burby.

One thing, however, is quite certain—and this fact I wish to bring out emphatically—that an absorption curve made in the metal that is used for filtration, such as is made for the average wave length determination, brings out many more factors that have a direct bearing on the doses as obtained and applied for therapy than any of the other methods of measuring the quality of the X-ray radiation.

CATHODE RAY DOSIMETRY[1]

By LAURISTON S. TAYLOR, Associate Physicist, Bureau of Standards, Department of Commerce, WASHINGTON, D. C.

IN the first few years after the discovery of X-radiation by Roentgen, little or no practical application of the rays was found in the field of medical therapy. When, finally, the field was opened up the workers were hampered by their very inadequate knowledge of the radiation. In particular, they knew of no precise way to express or describe the radiation they were using, and consequently there was a great loss of effort due to inadequate and inaccurate description of their experimental technic. In fact, as we all know, only within the last few years has it been universally possible to express the X-radiation used in medical treatment with any degree of exactitude. Indeed, there is still chance for improvement in this field, in spite of the very great recent advance made by workers in all parts of the world.

Cathode rays in air were first produced by Lenard, in 1894, but it remained until 1926 for Coolidge to produce this effect on a practical basis. Even before the work of Coolidge certain workers had speculated on the medical application, and even tried a few relatively simple biological experiments with these rays. Within the last two years, workers in this country and abroad have actively begun to seek medical uses for these high voltage cathode rays.

In the two original papers by Coolidge and Moore, they mentioned a few of the applications. I will simply repeat some of these in order to refresh our memories. They referred to the work of Strebel, who found that very short exposures to cathode rays would kill all kinds of bacteria. Coolidge killed such cultures as *Staphylococcus aureus, Bacillus coli,* etc. He and his coworkers also reported on a perfectly definite effect of the rays on animal tissues and on insects.

Two other applications of interest are the taking of shadow pictures of very delicate tissues, and the effect on certain chemicals.

The activation of ergosterol and cholesterol is one of the chemical effects of immediate interest to the medical man.

Thus, with the evident increase in the study of the effects of this radiation, we have anticipated a need for some precise method of describing the radiation at a given location.

A unit cathode ray beam may be described as *"that having an electron current density of 1 E.S.U. per square centimeter normal to the direction of the beam," and may be designated by "L."*

Since cathode rays are simply negatively charged particles, we can measure the number of rays by measuring, under carefully defined conditions, the current in the air between the tube window and a small plate at the desired position. This can be done to a rough approximation by the following method: A flat circular plate about one centimeter in diameter is surrounded by a six centimeter guard plate in the same plane. The edges of the two plates, where they adjoin, slope in such a way that the center plate is a truncated cone with the small face out. This is to prevent as much radiation as possible from striking the dielectric behind the plates and thus charging it up to a high potential. The central plate is connected through a shielded cable to a galvanometer. The guard ring, cable, galvanometer case, etc., are all connected to the anode of the tube. Thus the electron current to the center plate can be measured directly

[1]Read before the Fourteenth Annual Meeting of the Radiological Society of North America, at Chicago, Dec. 3–7, 1928.

and makes possible a quantity definition for a cathode ray unit.

It is recognized, of course, that in the above method several errors will be present. Certain of these will be eliminated in a system more recently designed but not yet sufficiently tested. Due to the electron atmosphere between the tube and measuring plate, it is expected that there will be a space charge which will drive ions from the ionized air to the plate. This will cause an increase in the measured current. It is possible to determine the magnitude of this quantity, and proper correction must be made for it. The entire galvanometer system must be directly connected to the cathode ray tube window. When both ends of the tube are at high potential, this means that the measuring system must be insulated for one-half the voltage and enclosed in a completely shielded and coronaless case. With one of the tubes used on a high voltage mechanical rectifier this was necessary. However, it is probable that in any medical application the anode will be grounded, thus greatly simplifying the measuring procedure.

In order to operate the tube under these conditions, a special transformer was grounded at one end and the other end led through a pair of high voltage kenetrons to the cathode of the tube. The anode was thus grounded and the measuring system set up, as above. This system also has the advantage that no troublesome stray fields are present and the galvanometer needs no special shielding. In order to afford protection to the operator from the extremely dangerous radiation the whole system was located in a large one-quarter inch lead room.

Another system was tried which appeared quite simple at first but which actually introduced serious errors. It consisted in the use of a plate attached to an electroscope, allowing it to charge negatively or charging it positively, and allowing it to discharge, in either case, measuring the time required for the operation. The results obtained are not easy to interpret correctly and I will not go into further detail, since the method was abandoned.

As to some of the other errors present. The cathode rays produce X-rays both from the air and the window of the tube. Since, however, the whole system is at zero potential no ionization current is present. There is a certain amount of photo-electric effect, but this was found to be very small compared with the electron current. There are also formed a certain amount of positive and negative ions which may impinge on the collector. The actual magnitude of this is uncertain just now, but it is believed to be quite small by comparison. There is also an uncertainty as to the exact measuring area of the collector, but with a more recent design this error is largely eliminated. It is quite necessary that all dielectrics in the measuring system be carefully shielded from cathode rays, since any charging on the surface will disturb the field and alter the amount of radiation impinging on the collector.

However, even with these and other uncertainties it is believed that the use of some such system as described above will mean an advance in the practical application of the radiation. Using such a system, we have mapped out the energy distribution about the window of two types of tubes, and it was found that this could be done with ease. The electron ranges as given by Coolidge were approximately checked.

Another quantity which will probably need to be known is the quantity-velocity distribution of electrons. To determine this most accurately it would be necessary to use a magnetic or electric spectrograph, but this is rather complicated for ordinary work. A simpler, but less accurate, method is being tried.

It is necessary to know the change in velocity distribution introduced by a varying

voltage on the tube and losses of velocity in the window. Using a source of constant potential we may determine a curve showing the relation between electron intensity and distance of the tube.

Thus, for the purpose of duplicating the treatment technic, it is only necessary to specify the distance from the tube to the material or patient and to give the intensity distribution curve as determined by the measuring method just described. This does not give the actual quantity-velocity distribution. However, it can be determined in the physical laboratory, and the biologist, upon submitting his curve, can be informed of its components with sufficient accuracy.

Until some determination of the relation between electron velocity and biological effect has been made, the measurement of quantity is the more important. It is hoped that the investigators who are following up the biological studies will take the trouble at the start to measure their radiation in some such unit as above, and thus avoid many of the early difficulties encountered in the use of X-radiation.

PHYSICAL FACTORS IN RADIATION THERAPY AND THEIR CLINICAL APPLICATION[1]

By J. L. WEATHERWAX, M.A., and B. P. WIDMANN, M.D.

Radiological Department, Philadelphia General Hospital and Graduate School of Medicine, University of Pennsylvania

IF the response to radiation therapy in the treatment of malignant disease is due to the direct action of the roentgen ray on the cell structure, it is then of paramount importance to adhere to some technic possessing a certain degree of flexibility and yet deliver to the tumor area the maximum amount of radiation. The necessity for a flexible technic is to allow for adjustments to the requirements of a particular case. The age, duration, location, and extent of involvement are so variable that the clinical judgment of the radiologist must alter any usual procedure of radiation management. The so-called "erythema dose" does not necessarily exist as a therapeutic dose

The problem of a radiation therapy technic, therefore, becomes more complicated, due to its inherent variability. If we could have one standard therapeutic dose, then the problem would be solved. Every radiologist would know dosage technic in the same terms.

There are a great many fractional dose technics described by various workers, most of which can roughly be put into one of two classes: a divided series of radiation treatments given within a period of about three weeks, or smaller doses of radiation extending over a longer period of time (4–8 weeks). Usually no systematic scale of dosage is adhered to, and more often the condition of the skin or the clinical response is the only guide.

The erythema dose will probably always be a variable factor, because the degree or threshold determination must necessarily depend upon the personal judgment of the radiologist. It is almost generally agreed that there is a variability of sensitivity to radiation in different patients, so that an absolute erythema factor is difficult to establish.

It is important, therefore, to have some standard to which all technics can be compared. The exponential curve (1) representing the probable biologic changes taking place in the tissue aims to keep up a continuous radiation or saturation within the limits of skin tolerance. This curve may not be an accurate representation of the true biologic changes in the tissue, but this should not contra-indicate its use. The saturation curve can act as a guide in giving radiation as well as a standard for comparing all fractional dose technics, and any errors in adjustments will always be relative.

It is important to know the quality and quantity of radiation used when treating patients. Sphere gap and meter controls are essential, but must be controlled by careful ionization measurements. Different types of rectification may give intensities of radiation with as much as 100 per cent variation.

The variable fluctuation of voltage and current necessitates a system of ionization measurement that will enable one to know the exact output of radiation during an actual treatment. Such a system (Fig. 1), described by one of us, shows (2) an ionization chamber, Part 1, with a filtration value of ¼ mm. of copper and 1 mm. of aluminum, fixed in a mounting that is permanent-

[1]From the Radiological Department of the Philadelphia General Hospital, Philadelphia, Pennsylvania. Presented before the Radiological Society of North America, at the Fourteenth Annual Meeting, at Chicago, Dec. 3–7, 1928.

Fig. 1. Continuous reading ionization system.

ly attached to the diaphragm. This is connected to a galvanometer system, Part 3, which is housed in a small cabinet above the control stand. A B-eliminator (Part 2) is connected in series with the ionization chamber and galvanometer. A pointer, shown as A, gives the skin-target distance and direction of the beam of radiation. This is removed during treatment. A visible record of the output of radiation is observed during an entire treatment. All mechanical factors are checked against discrepancies, and danger of filter omission is at once eliminated. By repeated ionization measurements we have established a constancy of factors in the radiation intensity

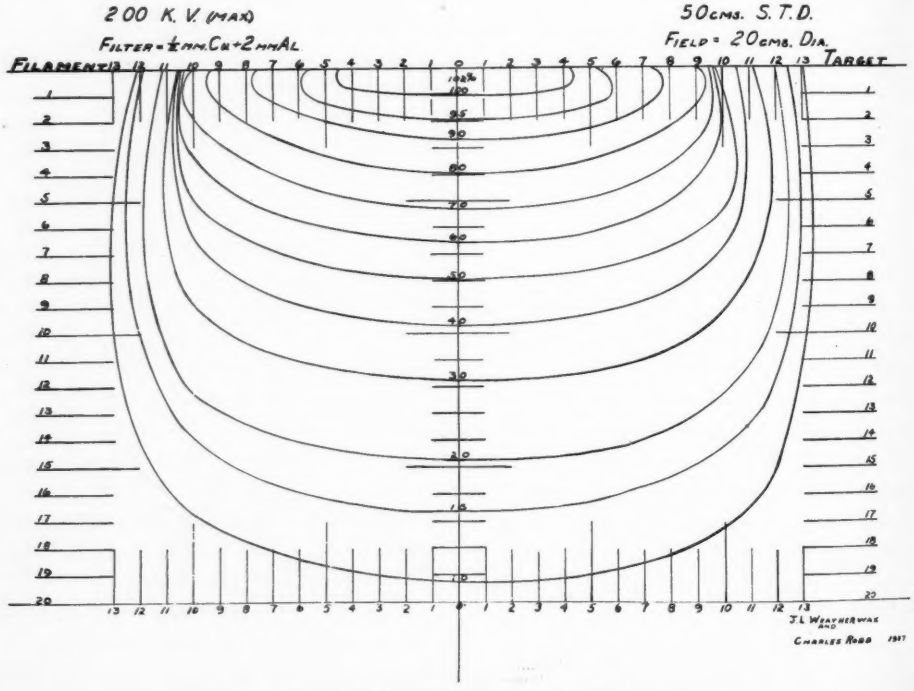

Fig. 2. Relative intensity curves in a water phantom.

for our equipment, giving a skin dose equivalent to 800 r-units.[2] This intensity of radiation represents a dose that is within the limits of skin tolerance or the so-called "threshold erythema."

Depth dose charts indicating relative radiation intensities in a water phantom have been established for varying sizes of ports (3). These charts (Fig. 2) have been made upon transparent celluloid in three different colors—red, yellow, and black.

Every patient is measured accurately and a diagram of the size and contour of the port is reproduced on thin transparent paper. A graphic visualization of the seat of the disease and the probable extent of involvement is sketched, on the basis of anatomical cross-section charts after Holfelder and Desjardins.

A series of 18 cross-section charts have been reduced to lantern slides 6½ × 4¼ inches (3). A kodak focusing device for enlarging photographs is used to project the exact dimensions of the anatomical chart. This chart is sketched on drawing paper and represents the exact dimensions of the part to be treated. The involved area is noted.

The transparent depth dose charts are arranged on the projected anatomical chart so that a calculated uniform intensity of radiation will be delivered to the diseased

[2]The erythema value equivalent to 970 r-units previously reported was found to be in error.

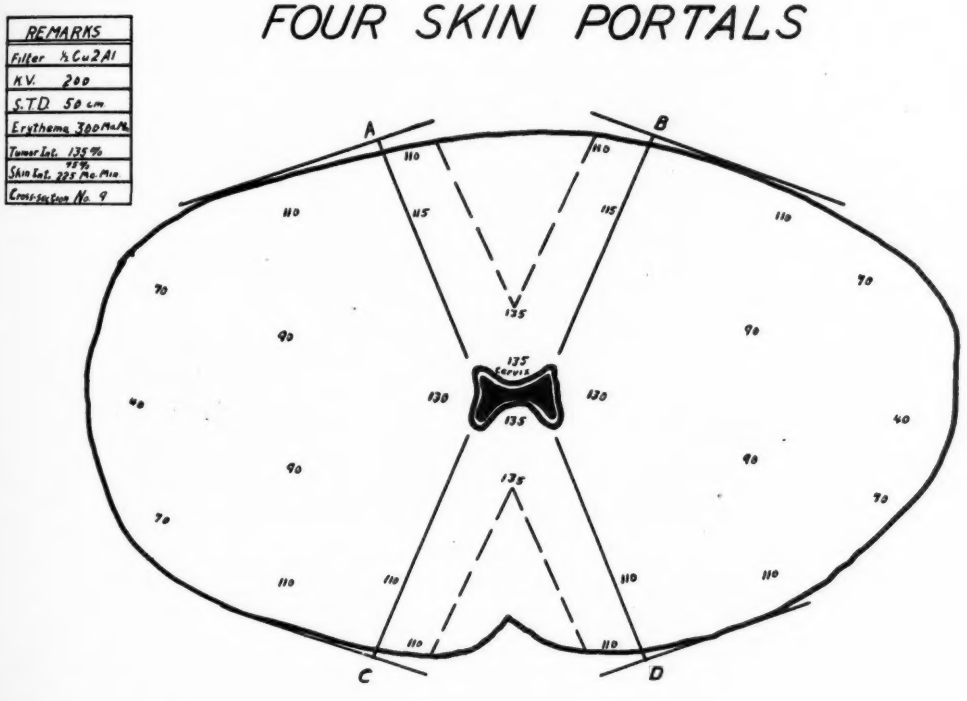

Fig. 3. Anatomical cross-section chart to size of patient, showing: (1) Number of fields; (2) Angle of incidence; (3) Tumor area; (4) Depth dose percentages.

area (Fig. 3). The number of portals and the angle of ray incidence are accurately visualized. Compensations can be readily adjusted to the size of the individual and depth intensity desired. For example, one-field technic may give the desired depth intensity, whereas a two-, three-, or four-field technic may be found necessary to deliver a desired depth dose.

Dr. Ewing states that the single, the fractional, and the prolonged doses of radiation produce different tissue reactions. If we are to properly evaluate our end-results, it is essential that we have a clear-cut record of intensity, with time. We know of no better way of representing intensity, with time, than by the graphic method. The intensity is represented as ordinate and the time in days as abscissa. The dates of the various treatments are given at the top of the graph.

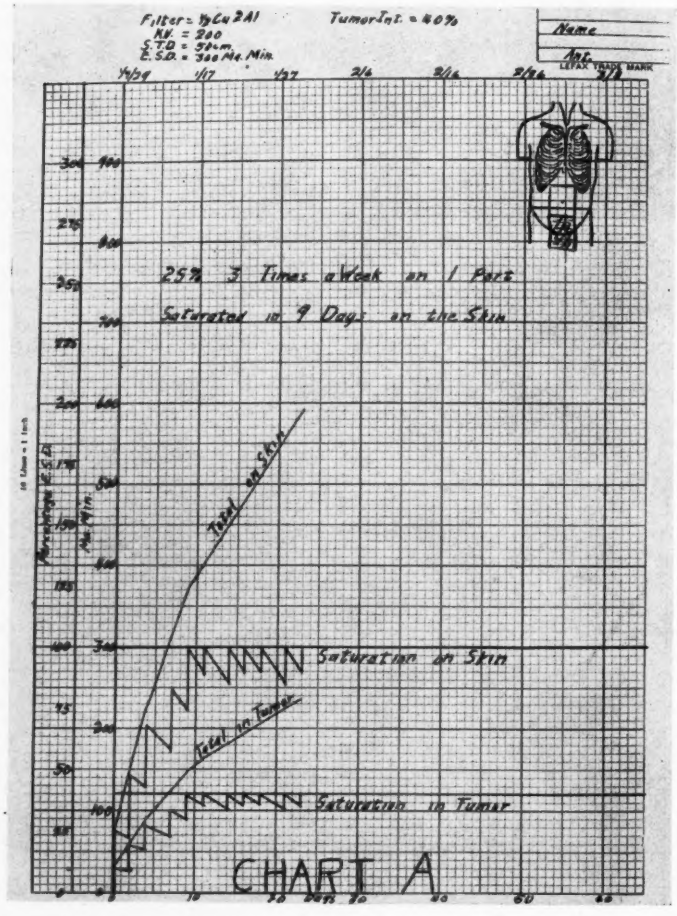

Fig. 4, Chart A, illustrating total intensities of radiation on skin and in tumor area as well as saturation values on skin and in tumor area, for one-field technic.

A percentage of an E.S.D. is given to

each area on 0 days or at beginning of treatment (Figs. 4 and 5). The probable loss of radiation in producing biologic changes in the tissue according to the saturation curve (1) is deducted, and shown by the downward sloping line. The next vertical line represents the second treatment of the same percentage of an E.S.D. This rate of giving radiation and deducting the probable loss is kept up until the skin area or tumor area is saturated at 100 per cent. After saturation has been reached for either the skin area or tumor area, the percentage of radiation given to one or more skin portals will depend upon the probable loss between treatments.

Curves representing the total amount of radiation are shown for each skin portal and tumor area. We seldom give more than two to two and a half of total E.S.D. to any one skin area or tumor area.

These charts indicate curves which represent the saturation in the tumor area, as well as the saturation on the skin.

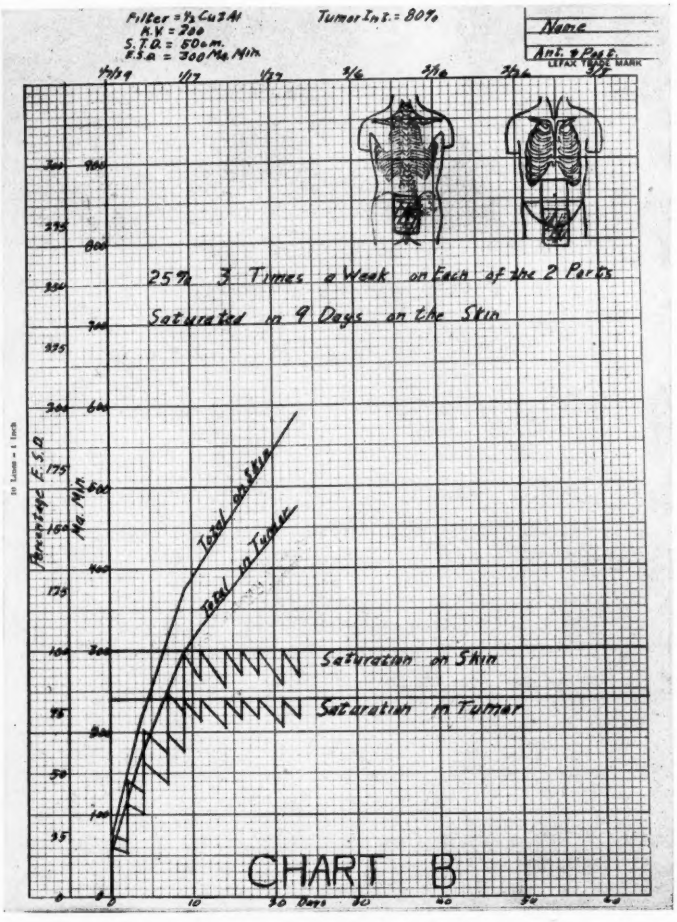

Fig. 4, Chart B, illustrating total intensities of radiation on skin and in tumor area as well as saturation values on skin and in tumor area, for two-field technic.

According to Figure 4, Chart A, it will be seen that if we saturate the skin of a single field, the tumor area will receive an intensity of only about 40 per cent saturation. It will be further noted by Chart B that tumor saturation is approaching the same intensity as the skin saturation. However, in a three- and four-field technic it will be observed (Charts C and D) that a 100 per cent tumor saturation for the average patient can be obtained with less than 100 per cent skin saturation.

If four portals of radiation are found necessary to give the requisite intensity in a given diseased area, a tumor saturation can be maintained, whether one chooses to treat one, two, three, or four portals at a sitting. It is essential to deliver the maximum intensity to the tumor area; whether one delivers this radiation by the massive dose tech-

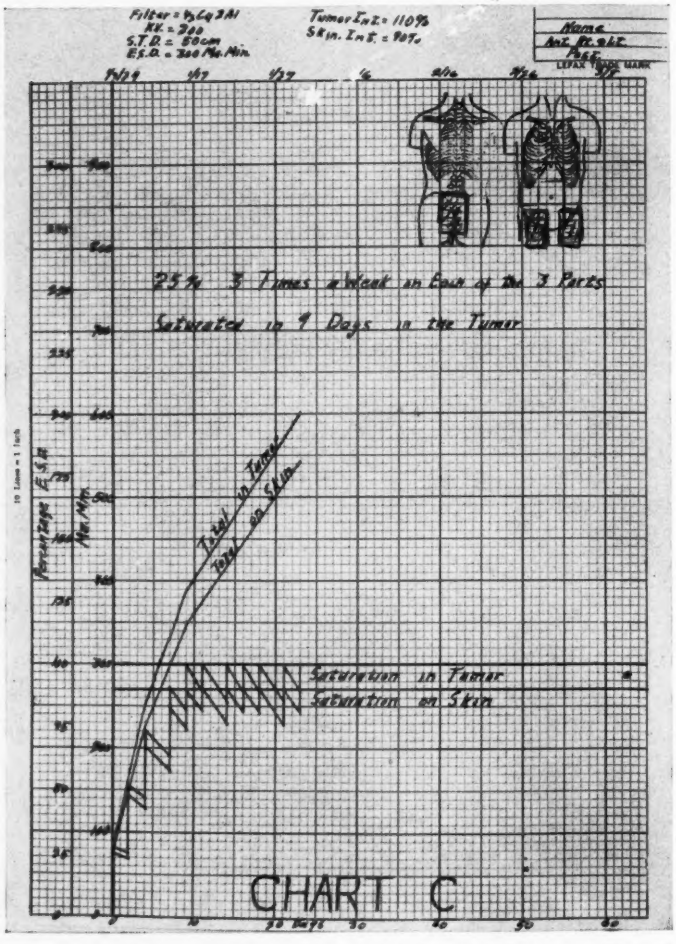

Fig. 4, Chart C, illustrating total intensities of radiation on skin and in tumor area as well as saturation values on skin and in tumor area, for three-field technic.

nic or divided dose technic so as to rapidly bring the tumor area to a threshold dose, must depend upon the individual experience. It will be noted, if four fields are treated at the same sitting, that a tumor saturation will be reached within three or four sittings, depending upon the percentage of surface radiation. The physical condition of the patient is so variable a factor that equal doses are not tolerated by all. Therefore, the desired tumor dosage can be obtained, whether 15, 20, 25, or 30 per cent of an E.S.D. is employed over each of four fields (Fig. 5).

Chart E.—Fifteen per cent of an E.S.D. is given to each of four skin areas three times a week. The tumor area is saturated to 100 per cent E.S.D. in about 14 days. Saturation is maintained for 11 days.

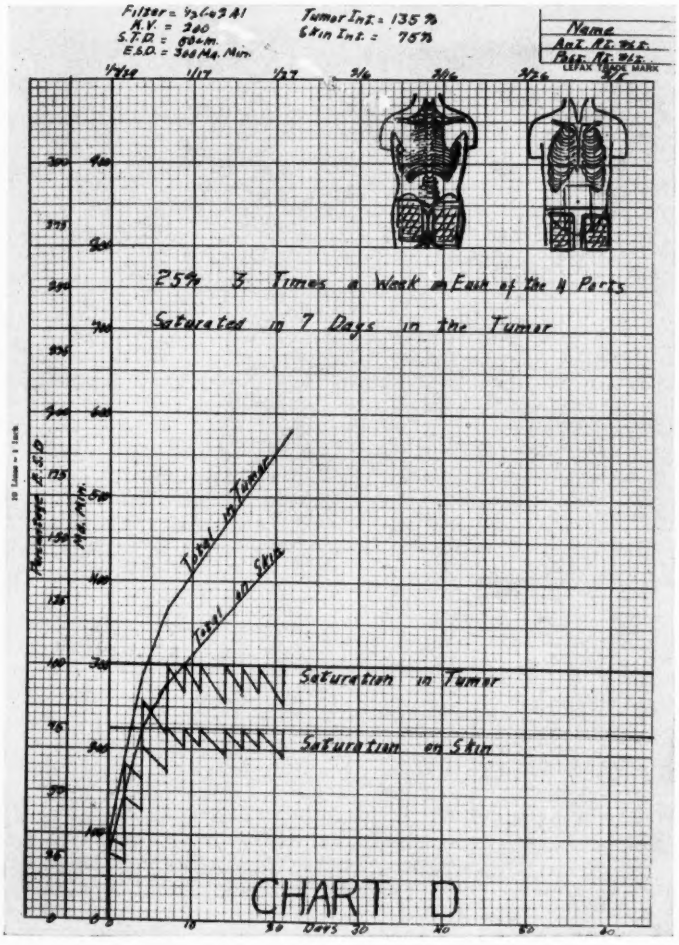

Fig. 4, Chart D, illustrating total intensities of radiation on skin and in tumor area as well as saturation values on skin and in tumor area, for four-field technic.

Chart F.—Twenty per cent of an E.S.D.

is given to each of four skin areas three times a week. The tumor area is saturated to a 100 per cent E.S.D. in 9 days. Saturation is maintained for 16 days.

Chart G.—Twenty-five per cent of an E.S.D. is given to each of four skin areas three times a week. The tumor area is saturated to a 100 per cent E.S.D. in 7 days. Saturation is maintained for 19 days.

Chart H.—Thirty per cent of an E.S.D. is given to each of four skin areas three times a week. The tumor area is saturated to 100 per cent E.S.D. in 4 days. Saturation is maintained for 21 days.

The apparent advantage in delivering as large a percentage of an E.S.D. as possible to each skin area at each sitting is that the tumor area becomes saturated more quickly and saturation can be maintained for a longer period.

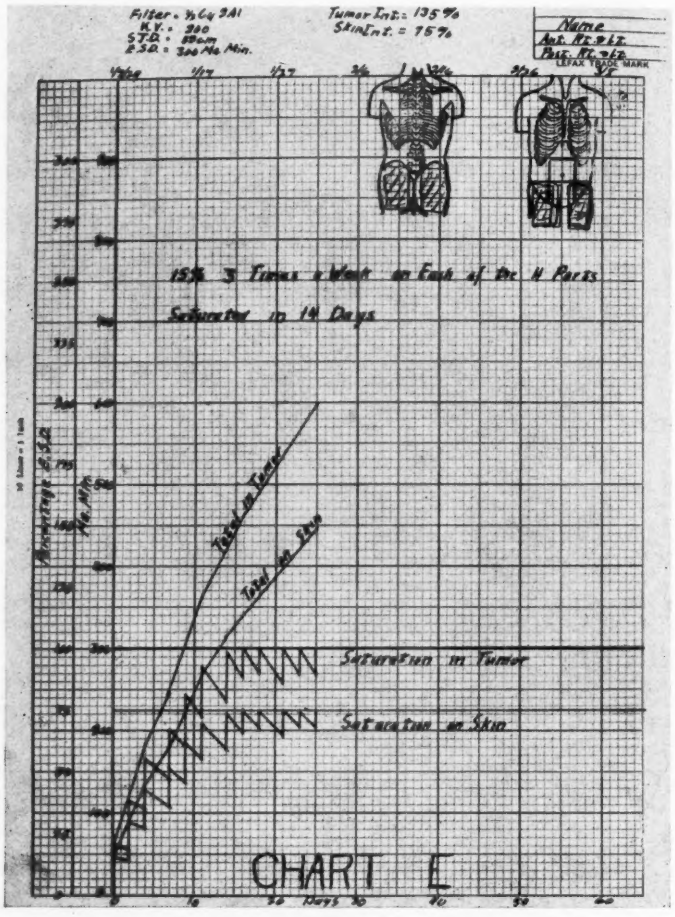

Fig. 5, Chart E, illustrating intensities on skin and in tumor area obtainable with 15 per cent of an E.S.D. given to four different fields at the same sitting according to the saturation technic.

The length of time that tumor saturation can be maintained at 100 per cent E.S.D. depends upon the extent of the disease and the condition of the patient. A total of 200 per cent of an E.S.D. can be delivered to the tumor area in a period of about 25 days, with about 150 per cent of an E.S.D. passing through each of four fields: the tumor area can be saturated at 100 per cent, while each skin area never exceeds 75 per cent saturation.

This procedure saves the skin. Constitutional reactions are practically *nil*. If the palliation has been sufficient and the physical condition of the patient permits, further radiation can be resumed within six to eight weeks. On the basis of the four-field technic to be given at one sitting, an intensive

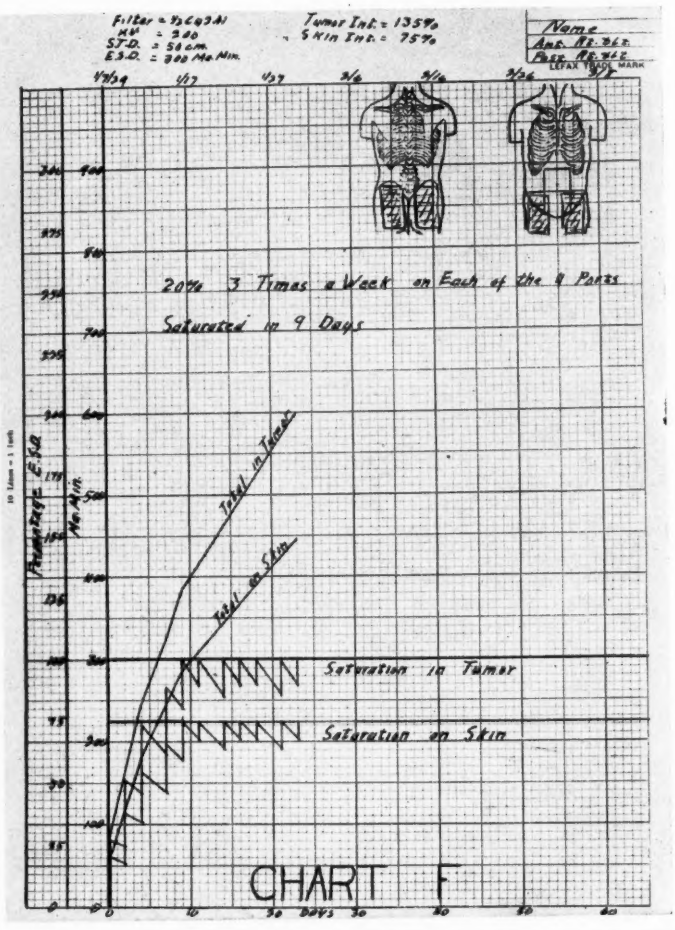
Filter = ½ Cu + Al
KV = 200
S.T.D. = 50 cm.
E.S.D. = 300 Ma Min.
Tumor Int. = 135%
Skin Int. = 75%
Name
20% 3 Times a Week on Each of the 4 Parts
Saturated in 9 Days
Total on Tumor
Total on Skin
Saturation in Tumor
Saturation on Skin
CHART F

Fig. 5, Chart F, illustrating intensities on skin and in tumor area obtainable with 20 per cent of an E.S.D. given to four different fields at the same sitting according to the saturation technic.

tumor radiation can be delivered and saturated within a period of two weeks.

The problem often arises that such a routine for each patient requires too much time. We have our department organized so that charts are kept by the same nurse and technician of the patients treated by them. This work is completed between nine and five o'clock daily.

The advantages, aside from more scientifically treating patients, seem to far outweigh any small amount of extra time spent in carrying on such a routine. To get the best results from radiation therapy, the tumor area must be vigorously treated, while,

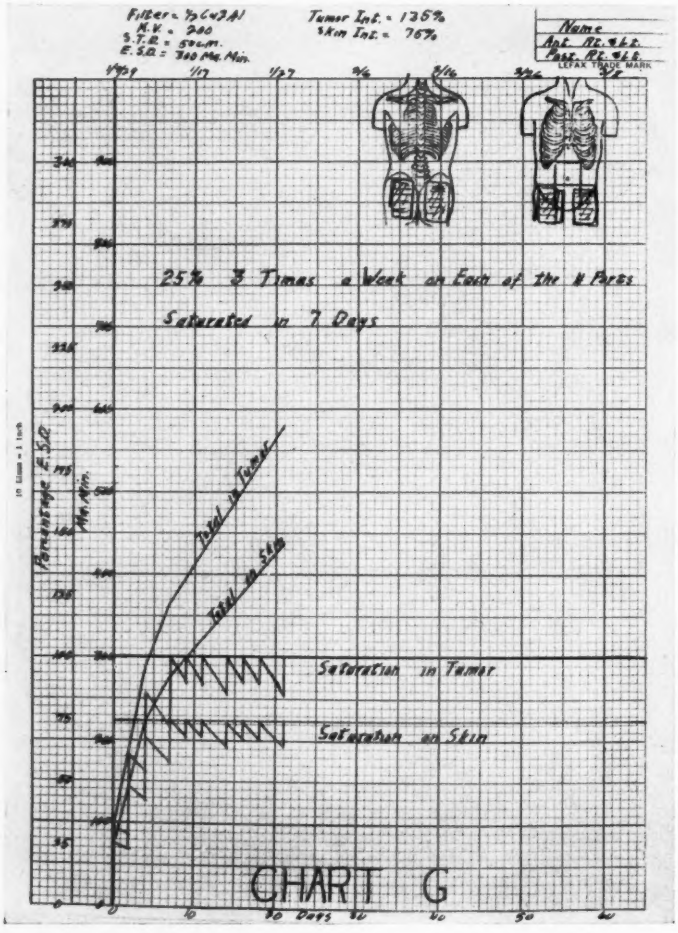

Fig. 5, Chart G, illustrating intensities on skin and in tumor area obtainable with 25 per cent of an E.S.D. given to four different fields at the same sitting according to the saturation technic.

a nurse and a technician treat, on the average, with one high voltage equipment 700 to 800 areas per month. This usually means that 300 to 400 different patients are handled. Cross-section charts and record

at the same time, the skin areas must be saved as much as possible for future radiation. This cannot be accomplished routinely without cross-section charts. These are applicable to face, neck, chest, abdomen, and extremities.

The graphic method of keeping records of dosage technic enables one to grasp quickly the rate at which radiation is given, as well as the quantity. The extra time spent in following such a routine is more than saved when one wishes to review end-results with technic.

The anatomical cross-section showing the fields of radiation, relative intensity distribution, and location of tumor area, along with the graphic representation of intensity —with time, is a rather complete picture of the series of treatments given the patient.

It is interesting to note that an equal in-

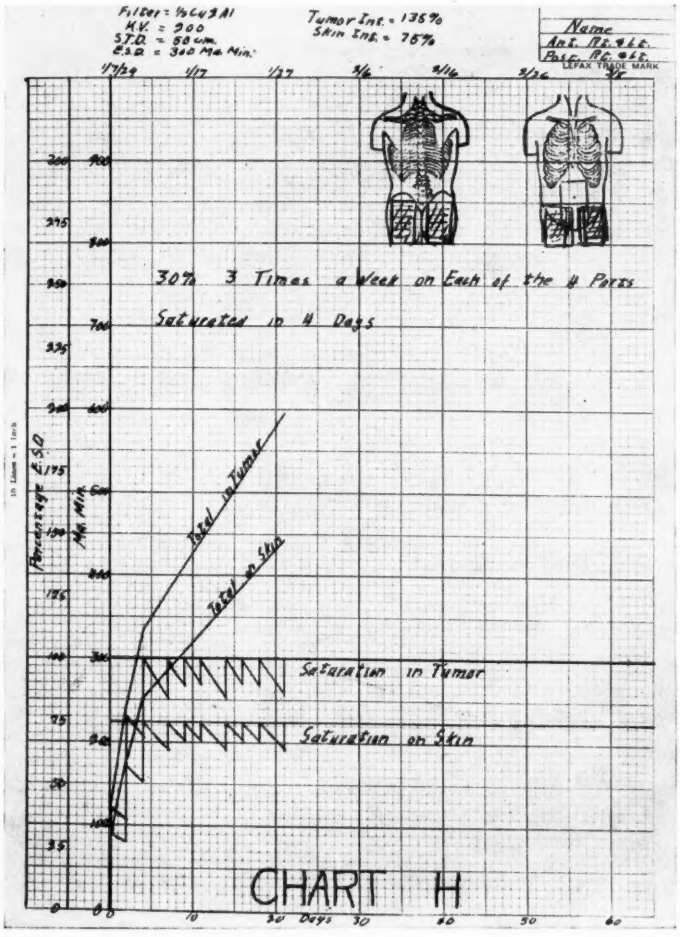

Fig. 5, Chart H, illustrating intensities on skin and in tumor area obtainable with 30 per cent of an E.S.D. given to four different fields at the same sitting according to the saturation technic.

tensity of radiation can be obtained in the tumor area whether 15, 20, 25, or 30 per cent of an E.S.D. is used. The only difference is that it takes longer. This increase of time is not so important.

Whether it is better to bring the treatment up quickly by large single doses through one portal of entry, or smaller doses through four different portals at one sitting, or to prolong the radiation with multiple small doses cannot be stated.

There is certainly no technic that has reached an unalterable refinement.

There seems to be a marked clinical improvement in the cases treated by the four-field technic, as compared to those treated by a single dose at each sitting. This improvement is especially noticeable in the so-called "frozen pelvis." The possible advantage of getting a balanced distribution of radiation throughout the affected area and bringing the depth intensity up to saturation gradually and uniformly must be considered.

CONCLUSION

Systematic records of all radiation treatments are of paramount importance. End-results can readily be compared and various technics given proper evaluation.

The graphic chart probably illustrates all of the conditions of treatment, such as: (1) total intensity in tumor area; (2) total intensity on skin; (3) saturation value in tumor area, and (4) saturation on skin. These lines are plotted so that they can be read in terms of percentage of an erythema skin dose or in terms of milliampere-minutes.

Cross-section charts and depth dose charts aid one to visualize quickly the direction of the rays, so that depth intensity can be regulated with almost exact precision. The number of fields will be controlled by the desired dose effect.

Progress and efficiency in radiation therapy entail meticulous application to the details of the underlying physical principles, and a systematic adaptation of accurate records to properly evaluate clinical results.

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SKIN TOLERATION DOSES IN ROENTGEN UNITS AND THEIR RELATION TO THE QUALITY OF RADIATION[1]

By P. M. HICKEY, A.B., M.D., Professor of Roentgenology, University of Michigan, Ann Arbor, Michigan, and ERNST A. POHLE, M.D., PH.D., Professor of Radiology, University of Wisconsin, Madison, Wisconsin, with the collaboration of G. A. LINDSAY, PH.D., Associate Professor of Physics, and J. M. BARNES, B.S., M.D., Senior Instructor in Roentgenology, University of Michigan, Ann Arbor, Michigan

SINCE the roentgen unit has been adopted as the international unit in roentgen therapy, an earnest endeavor must be made by our Society to induce all roentgenologists of this country to use the unit in their work. Editors of medical journals can do their share in furthering this desirable development by requiring all authors to express data on treatment work in this reproducible unit. A number of problems arise in that connection, problems which have been investigated and discussed before but are far from being solved.

QUALITY OF ROENTGEN RAYS

Last year, two of us (1) presented before this Society the results of investigations dealing with the comparison of a number of methods to define the quality of roentgen rays. To repeat it once more, quality measurements are necessary because most of our ionization chambers show a dependence on the wave length. While it is also true that transformers with mechanical rectifiers produce different qualities of roentgen rays even if they are running at the same setting as controlled by a kilovolt meter alone, it must be stated that the spectral energy distribution of roentgen-ray beams emitted by different Coolidge tubes running at the same potential as measured by a sphere gap is approximately the same.[2]

This is particularly true if filtered radiation is used, because then the different thickness of the glass wall of the different tubes does not influence very much the penetration of the X-ray beam. That the wall thickness is an important factor in superficial therapy with unfiltered radiation has been demonstrated by Wucherpfennig (2).

Several years ago, Glocker (3) published ample data showing that potential and filter do determine the quality of roentgen rays if the potential is measured correctly. The agreement in quality among different machines is better in the case of valve tube rectification than in apparatus with mechanical rectifiers. If, therefore, in the paper mentioned before (1), different installations were found to have about the same quality of radiation under identical operating conditions, this is really not so surprising if analyzed properly. It also does not render quality measurements superfluous because it is often simpler to define quality by ionization measurements. That it must be possible practically to produce roentgen-ray beams of the same quality by different apparatus in different localities may be deduced from the paper by Meyer and Glasser (4), who compare, in Table III of their article, the output of seventy machines. In each instance the quality is characterized by the potential, the tube current, and filter only. We are confident that the authors satisfied themselves of the identity of the quality of radiation in all cases, either by spectral or absorption analysis. It seems advisable, however, to agree on some factor which defines the penetration of an X-ray beam, based on actual measurements in the emitted spectrum. Although we still believe that the recording of the spectrum or the

[1] Read before the Radiological Society of North America at the Fourteenth Annual Meeting, at Chicago, Dec. 3–7, 1928.

[2] If kenetrons in connection with condensers are used for producing constant potential, the maximum of intensity is shifted towards the shortest wave length in the spectrum as compared with an apparatus of the mechanical rectifier type.

plotting of a complete absorption curve in copper or aluminum are the most exact methods, there are a number of simpler procedures accurate enough for practical purposes. In Germany, Holthusen (5) has known to us which permits the derivation of a quality factor by carrying out only two measurements is the determination of the effective wave length, introduced by Duane. We studied, therefore, the behavior of two

TABLE I

Radiation	Lambda effective through				H. V. L.		600 *R* (primary energy) in min.
	2.0 Al.	4.0 Al.	0.25 Cu.	1.0 Cu.	Al.	Cu.	
I. 80 K.V. 0.20 Cu.	.33	.32	.29	.25	4.0	.16	36[3]
II. 180 K.V. 1.0 Al.	.35	.304	.28	.21	5.2	.15	13[4]

[3]F. S. D. = 20 cm.; 5 ma. [4]F. S. D. = 50 cm.; 4 ma.

recommended the determination of the half value layer in copper, while in this country, Meyer (6) prefers the half value layer in aluminum. He contends that the handling of very thin sheets of copper as required for radiation produced by potentials below 100 K.V. is rather difficult. As a whole, it is always unsatisfactory to express the penetration of an X-ray beam by one figure, from a physical standpoint. In the practice of roentgenology, however, it is sufficient if the quality factor determines all properties of the radiation of importance in clinical work. While we agree with Holthusen that copper is certainly superior to aluminum as filter material in quality measurements for high potentials, we feel inclined to give preference to a method which permits the physician to get satisfactory results with a minimum of measuring. Holthusen has proved that two X-ray beams of the same half value layer in copper but of entirely different character as shown by the absorption curves have the same effect on the skin and are absorbed in the same manner in tissue. Many readings of the ionization instrument are necessary to determine the half value layer. The only method entirely different X-ray beams of approximately the same effective wave length, along the lines of Holthusen's work. In order to permit a comparison with his results, we have chosen two types of radiation similar to his, one at 80 K.V. and 0.2 Cu. and one at 180 K.V. and 1.0 Al. The values for lambda effective for different filter thicknesses are compiled in Table I and will be discussed later in this paper. The absorption curves in copper of these two radiations demonstrate the points discussed (Fig. 1). With both radiations, skin tests were carried out applying 600 *R* (primary energy) to small fields, and the absorption in water was recorded with a Siemens Dosimeter in a phantom built for that purpose (Table II).

For the skin reactions, we chose the forearm and the abdomen of three adults and

TABLE II

K.V.	Filter	Intensity in 10 cm. depth
80	0.2 Cu.	30.7%
180	1.0 Al.	32.3%

recorded the erythema with a tintometer as described by Schall and Alius (7), using their original dye solution, but with a modified scale. In no case could we detect a difference between the degree of reddening

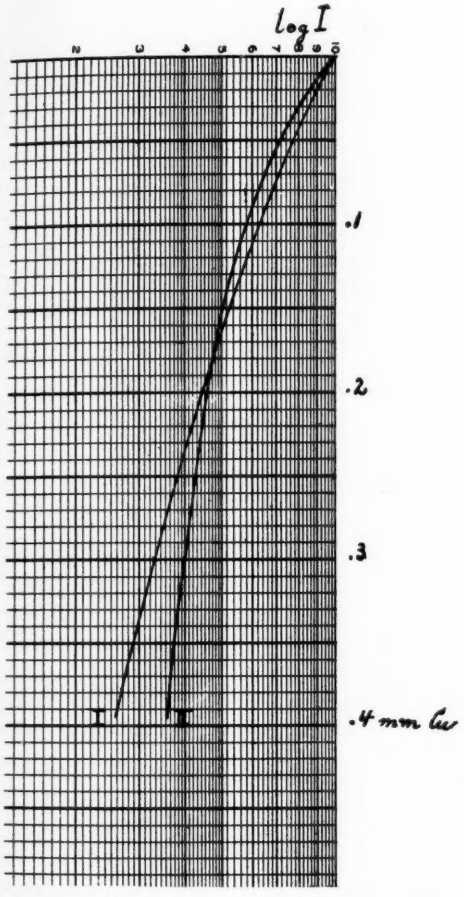

Fig. 1. Absorption curves in copper: (1) 80 K.V., 0.2 Cu. (2) 180 K.V., 1.0 Al.

amounting to more than one step in our arbitrary erythema scale. This leads us then to recommend the determination of the effective wave length as the method of choice in characterizing the quality of a roentgen-ray beam in roentgenologic practice. We emphasize once more that the physicist's requirements are different. In each instance it is necessary to state what potential and filter have been used in order to determine the percentage of transmission. It is obvious that the results must vary with the amount of filter interposed unless the beam examined is already homogeneous. Duane and his co-workers (8) have drawn attention to that point very recently; it can be summarized in their words: "This, indeed, is the principle of filtration." We emphasize this again because in the previously mentioned paper (1) the effective wave length of the same beam was recorded differently, according to whether the transmission was measured in aluminum or in copper. The difference was greater for more heterogeneous beams. No explanation of this well known fact was given, but exception has been taken to these results (9). This led us to explain how analysis based on some fundamental laws of X-ray physics shows that these results, as published before, can theoretically be predicted and are physically sound.

SKIN REACTIONS

After a simple and reliable method of defining the quality of radiation had been established, we proceeded to apply an identical number of *R*-units to the skin of adults, in one sitting on fields of 3 cm. × 3 cm. over a range of radiation from 60 K.V. unfiltered (lambda effective equal to .61 Å. measured through 2 mm. Al.) to 200 K.V. filtered through 1.0 mm. Cu. (lambda effective equal to 0.138 Å. measured through 1 mm. Cu.). A Siemens Dosimeter placed in the beam during each skin exposure controlled the uniformity of the dose applied. Observations were made daily, if possible, for the first ten days, and values are recorded in Table III for 1 day, 6 days, 2 weeks, 4 weeks, 8 weeks, and 12 weeks following the exposure.

Before discussing the figures represented there, we would like to say a few words regarding the *R*-unit used in these experi-

TABLE III

No.	K.V.	Filter	*R* (in air)	Reaction						
				6-8 hrs.	1 day	6 days	2 wks.	4 wks.	8 wks.	12 wks.
1	75	—	500	—	0	2	4	3 p.	3 p.	darker
	200	.5 Cu.	500	—	0	2	3	3 p.	2 p.	both fading
2	75	—	600	3	2	5	4	—	3+p.	—
	130	.25 Cu.	600	2	2	4	3	—	2 p.	—
3	75	—	500	—	0	—	3	3 p.	darker	—
	200	.5 Cu.	500	—	0	—	1	2 p.	both fading	—
4	75	—	500	—	0	3	—	—	darker	—
	200	.5 Cu.	500	—	0	2-3	—	—	pig-mented	—
5	75	—	600	—	1	1	3+p	3 p.	—	—
	200	.5 Cu.	600	—	1	1	2 p	2+p.	—	—
6	75	0	500	1+	—	2	3 p	—	4 p.	—
	200	.5 Cu.	500	1	—	2	2 p	—	3 p.	—
7	75	0	500	—	0	—	{2 {2	2+ 2	4 4	—
	200	.5 Cu.	500	—	0	—	{3 {3	3+ 3	3 3	

ments. We are sure that it is identical with the *E*-unit of Duane, with the *R*-unit of the German Bureau of Standards (Behnken), and with that of Kuestner (Göttingen) within a variation of about 6 per cent. If one employs a large ionization chamber in connection with a galvanometer and standard cell, as described by Duane and Lorenz (10), the unit can always be redetermined. Through the courtesy of Professor Duane, a duplicate of his standard chamber has been set up in our laboratory, which permits the reproduction of Duane's unit within less than 1 per cent of error. As it is convenient to carry out daily measurements with an instrument having a small ionization chamber made of material of low atomic number, some method of controlling its calibration in *R*-units must be incorporated. We believe that everyone agrees on this particular point. The method recommended by Kuestner (11), whose instrument has a large ionization chamber, and, therefore, can employ a small unfiltered radium preparation (Beta and Gamma rays), is very practical. The quotient derived by dividing radium and roentgen seconds (discharge time due to roentgen rays or due to the radium preparation), multiplied by a constant, gives the number of *R* per time unit. In this way any change in the sensitivity of the instrument is, of course, elimi-

TABLE IV

Date	*R* scale	Remarks
9-23-26	4.7	Originally calibrated in Germany. W. I. No. 192
10-24-27	5.04	Calibrated by W. Duane, Boston
3- 6-28	4.94	Calibrated against Kuestner instrument
7-30-28	5.02	Calibrated against W. I. No. 230 (calibrated in Germany)
11-23-28	5.14	Calibrated against W. I. No. 243 (calibrated in Germany)[5]

[5]The calibration of this instrument is controlled by a radio-active substance.

Fig. 2. Upper field, 130 K.V., no filter; lower field, 130 K.V., 4.0 Al. 500 *R*, sixth day.

Fig. 3. Upper field, 75 K.V., no filter; lower field, 200 KV., 0.5 Cu. 600 *R*, one month.

Fig. 4. Upper field, 200 K.V., 0.5 Cu.; lower field, 75 K.V., no filter. 500 *R*, six weeks.

nated. For small ionization chambers, a larger amount of radium (about 50 mg.), with sufficient filtration to eliminate Alpha and Beta rays, must be used, according to the investigations of Behnken and Jaeger (12).

Our Wulf Ionometer No. 192 was calibrated in Germany, in September, 1926; that the original unit is still the same and has not changed materially since the instrument arrived here is proved by the figures in Table IV. Data for the filtered radiation only are given. It appears from Table IV that Instrument No. 192, calibrated in September, 1926, agrees with Instruments No. 230 and No. 243,[6] calibrated in Germany nearly two years later, within 10 per cent. This speaks well not only for the instrument but also clearly shows that the original unit has remained practically unchanged. The agreement with the Duane unit and the unit transported by the Kuestner instrument is also very satisfactory. These findings are given here because the constancy of the original calibration has been questioned.

From the data presented in Table III, it is evident that there exists little difference in the skin reaction on small fields if the same number of *R*-units of radiation of different penetration (60–200 K.V.) is applied. Besides the seven cases reported there, fourteen more patients have been under observation up to six weeks, showing essentially the same reaction. While the erythema for both long and short wave radiation was in all cases approximately the same, the pigmentation in the field exposed to the long wave length showed a definite preponderance. In one or two cases this led to a mild degree of desquamation, around the sixth week. On the other hand, there were a number of patients in whom a response to the highly filtered radiation was more pronounced. There may even be a difference between fields of the right and left arm of the same person after exposure to identical doses of the same quality of radiation. Figures 2, 3, 4, and 5 demonstrate all these points better than words. Undoubtedly part of the dominance in the pigmentation for long wave lengths is due to an error in dosage, if small ionization cham-

[6] We are indebted to Dr. Paul Hodges and Dr. C. S. Capp, of the University of Chicago, whose courtesy made this comparison possible.

TABLE V[7]

K.V.	Filter	*R* per second 60 cm. F.D.	Equivalent E.D. in minutes 23 cm. F.S.D. 1.5 × 1.5 cm. field	*R* (in air) 1.5 × 1.5 cm. field	*R* (in air) 6 × 8 cm. field	*R* (in air) large field
185	1.0 Cu. + 1.0 Al.	0.101	16.5	680	540	485
180	0.5 Zn. + 1.0 Al.	0.147	12	720	575	515
145	3 mm. Al.	0.144	12	710	590	540
110	2 mm. Al.	0.134	12.5	690	575	530
110	1 mm. Al.	0.172	10	700	580	540
60	0.5 mm. Al.	0.137	13.5	750	680	625
60	No filter	0.231	8.2	750	680	625

[7]Reprinted from Hess, *loc. cit.*

bers are used. The wall, although made of light material, absorbs some of the long waves, which, on the other hand, reach the skin and are biologically effective.

DOSAGE IN PRACTICE

We conclude from the experiments described in the previous section that 500 *R* (primary energy) can be applied to the skin in small fields (3 cm. × 3 cm.) from lambda effective equal to 0.61 Å (60 K.V., no filter, through 2.0 Al.) to lambda effective equal to 0.138 Å (200 K.V., 1.0 Cu. filter, through 1.0 Cu.), without undue reactions during the period of observation (up to 3 mo.). This confirms our previously published findings (1). For expressing the number of *R*-units (measured in air) required to produce an average erythema (skin toleration dose[8]), we have used before the term "roentgen value"; the same word has been introduced by Holthusen but he gave it a different definition. In order to prevent possible misunderstanding, we would suggest calling the number of *R*-units as measured in air and which designate a skin toleration dose under certain conditions of radiation, the "air value," while the corresponding figure giving the number of *R*-units as measured on the patient may be called "skin value." The latter would then include the back-scattering from the patient. For large fields a reduction has to be made allowing for this additional factor in the surface dose. Table V, reprinted from Hess (13), illustrates this point well. He regards 700 *R* (air value) as his average figure for an erythema, a dose which is beyond the maximum safe dose according to Kuestner (14).

We are facing, therefore, a very impor-

Fig. 5. Right arm, upper and lower fields, 75 K.V., no filter; left arm, upper and lower fields, 200 K.V., 0.5 Cu. 500 *R*, seven weeks.

[8]To avoid conflicts in terminology, the term "toleration dose" has been chosen. The "tolerance dose" is the maximum safe dose a roentgenologist can bear in daily work without ill effects (Barclay, Glocker, and Mutscheller).

tant question: Is it permissible in daily practice to use the same amount of primary energy throughout the whole range, from 60 K.V. unfiltered up to 200 K.V. and 1.0 Cu.? While Holthusen (*loc. cit.*) and Hess (13) believe this to be safe, we have taken the stand before (1) that "We would like to restrict this statement and say that no immediate harm or injury results from this procedure, but that only observation over a period of years will enlighten us regarding the possibility of late reactions following the application of what is considered today a rather high dose of unfiltered roentgen rays. For the present, we feel free to regard the following dose[9] as safe according to our experience." Anyone who has observed late reactions appear years and years after exposure to roentgen rays will certainly agree with this cautious point of view. It is a well known fact that there is a wide gap between experiments carried out under special precautions in a well equipped laboratory and the same performance carried out in daily practice. How one can construe from this conservative attitude that we doubt the results of our investigations on this subject is beyond comprehension (See RADIOLOGY, 1928, XI, 87). As far as the curves of Meyer and Glasser are concerned, who are plotting the number of *R*-units required for a threshold erythema dose given in one sitting against the quality of radiation (half value layer in Al.), it seems that we are really not so far apart. These authors (15) have published the number of roentgen units required for their erythema doses. For unfiltered radiation at 75 and 100 K.V., they approach very closely a mean value of 500 *R*, while for filtered radiation in deep therapy, using large fields, they go up to doses (900 *R* primary energy for 215 K. V., 0.75 Cu. + 1.0 Al., amounting to approximately 1,260 *R* on the patient) which we would not dare to give in one sitting. According to the experience of the German clinics,[10] 715 *R* (primary energy) may cause a burn of the third degree. At any rate, it is hard to conceive that 900 *R* (in air) or 1,260 *R* (on the skin) of filtered radiation produced only a threshold erythema on a field of 20 cm. × 20 cm., if applied in one sitting. Such a reaction was selected as standard by Meyer and Glasser (15). This whole discussion assumes, of course, that we have at all times used the same roentgen unit. Lately, Glasser (16) believes that the primary energy required for an erythema on small fields is independent of the wave length, but he still doubts that this holds true for large fields. For the latter, the relation can not be exactly the same, due to the back-scattering effect, which changes with the average wave length. Our own viewpoint has been set forth in the previously mentioned paper (1). We repeat that each roentgenologist has to assume the responsibility for his dose. Data published in literature can only serve as guides. It is important, however, that the reproduction of any dose reported is made possible now only through the acceptance of a well defined unit in connection with a quality factor accurate enough for practical purposes. Our experience regarding the exposure of large fields will be reported as soon as a more reliable method of measuring the amount of back-scattering on the patient has been developed.

[9] *Loc. cit.* (1), p. 307, Table 6.

[10] See the questionnaire of Kuestner (14).

SUMMARY

1. The measuring of the effective wave length (Duane) is proposed as quality factor for practical purposes in radiology. It is necessary to indicate always the potential, the filtration, and the transmitting material used in the test.

2. Further studies of the relation between skin toleration doses in roentgen units and their relation to the quality of radia-

tion have confirmed our previous investigations. It seems safe to assume that small areas (3 cm. × 3 cm.) may be exposed to 500–600 *R* (primary energy) with all types of roentgen rays used in practice. We examined a range from lambda effective equal to 0.61 Å (60 K.V., no filter, through 2.0 Al.) to lambda effective equal to 0.138 Å. (200 K.V., 1.0 Cu. filter, through 1.0 Cu.).

3. Caution should be exercised in transferring these results to the exposure of large fields in daily practice, because of the fact that there exists no simple method of measuring the exact amount of back-scattering on the patient.

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THE RELIABILITY OF THE r-UNIT FOR THE MEASUREMENT OF ROENTGEN AND RADIUM RADIATION[1]

By OTTO GLASSER, PH.D., and U. V. PORTMANN, M.D.
Cleveland Clinic Foundation, CLEVELAND, OHIO

THE International Dosage Unit "one r," which was adopted at the International Congress of Radiology in Stockholm on July 25th of this year, has caused the "Solomon R-unit" to lose some of its practical importance as a dosage unit. However, from an experimental point of view, its relationship to the "International r-unit" is of considerable consequence.

In our laboratory we have been endeavoring for some time to correlate the "Solomon R" with the "Electrostatic R," and first presented the results of this comparison at the meeting of the American Roentgen Ray Society in 1927 (1). At that time we stated the "Solomon R-unit" to be identical with the "Electrostatic R-unit," if in the Solomon definition the distance between the ionization chamber and the radium preparation be reduced from 2 cm. to 1.37 cm. Later these measurements were repeated with greater accuracy by means of our new type of condenser dosimeter.

The method by which this investigation was conducted and the results which were obtained have already been published (2). Some of the more important information is here reproduced in Figure 1. In this diagram the ordinate represents the square of the distance between the ionization chamber and a radium preparation of 1 gram, which is filtered with ½ mm. of platinum. The abscissa represents the number of "International r-units." *The heavy line* shows the data obtained by the use of the experimental arrangement of Solomon. *The fine line* represents similar data, but for ideal conditions; that is, for point source of radium and a point ionization chamber. *These latter values for ideal conditions are obtained by extrapolation from the data obtained when measurements are made at relatively great distances.* In the lower right hand corner of the diagram are reproduced the data for the shorter distances, but on an enlarged scale. From this diagram, then, we may determine the important relationship between the "International r-unit" and the "Solomon R-unit."

1. At 2 cm. distance (radium to ionization chamber), using the Solomon experimental arrangement, we find that 1.96 "Solomon R" is equivalent to one "International r."

2. At 2 cm. distance (radium to ionization chamber), using the ideal arrangement, we find that 1.62 "Solomon R" is equivalent to one "International r." In other words, these results may be stated as follows:

3. One "Solomon R" (using Solomon's experimental arrangement) is equivalent to one "International r" if the distance between radium and the ionization chamber is reduced from 2 cm. to 1.38 cm., and

4. One "Solomon R" (using an ideal arrangement) is equivalent to one "International r" if the distance between radium and the ionization chamber is reduced from 2 cm. to 1.54 cm.

At this time we may draw some interesting deductions from this information: First, it permits us to compare directly doses as measured in "Solomon R-units" with doses measured in "Electrostatic R-units"; second, and most important, is the check which may be made upon the reliability of the r-unit in measuring roentgen and radium radiation.

The figure 1.62 which we obtained as representing the ratio of the "International r"

[1]Read before the Radiological Society of North America, at the Fourteenth Annual Meeting, at Chicago, Dec. 3–7, 1928.

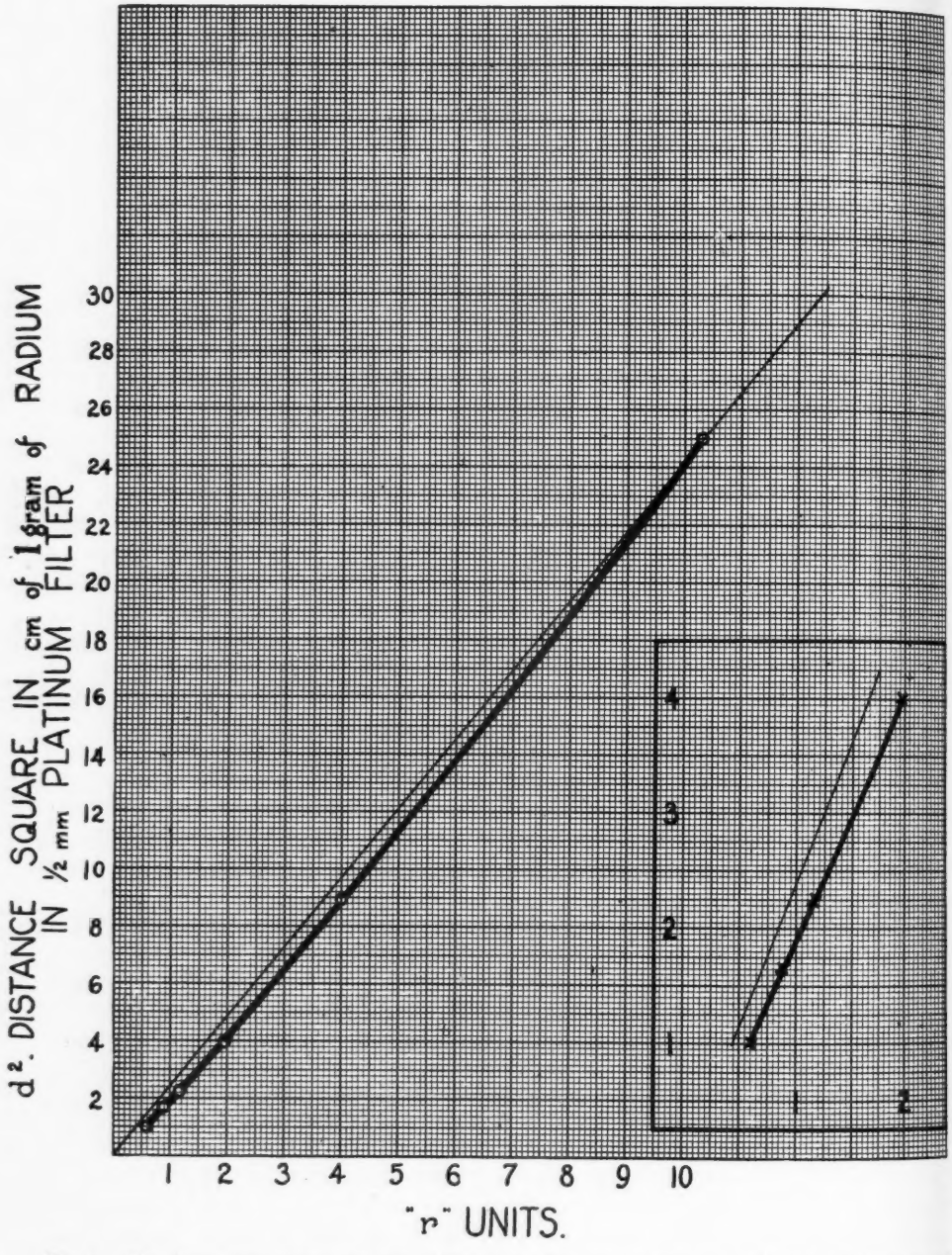

Fig. 1. The *heavy line* shows the data obtained by the use of the experimental arrangement of Solomon. The *fine line* represents similar data, but for ideal conditions. (See further explanation in text.)

to the "Solomon R" was also recently established within an accuracy of 1 per cent by Behnken and Jaeger (3), with an experimental arrangement which was entirely different from ours. Our comparisons (4) of various "Electrostatic R-units," and those made by Behnken (5) last year established the fact that the "Electrostatic R-units" at the Physikalisch-Technische Reichsanstalt in Berlin-Charlottenburg, at the Roentgen Institutes of Prof. Holthusen in Hamburg, of Prof. Grebe in Bonn, of Dr. Kuestner in Göttingen, as well as in Dr. Duane's laboratory in Boston and in our own are in satisfactory agreement. We have now added another gratifying proof in the work of Behnken and ourselves that these units are in agreement.

It would seem, therefore, that the problems of the proper construction for ionization chambers and of the establishment of the reliability of the r-units have for some time been satisfactorily solved. Furthermore, our comparison of the units has proved the reliability of the r-unit, not only as it applies to roentgen radiation, but also to the gamma radiation of radium. At the International Congress we presented data for dosage in r-units as measured for the beta rays of radium, *and we feel that we can continue to make the statement that the r-unit may be used with a great degree of accuracy for the dosage unit of both roentgen and radium therapy.*

The results of this investigation, which have been published in *Strahlentherapie*, agree with the findings of Behnken. The researches were made independently, however, and the conclusions which we drew were new.

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DISCUSSION

Dr. Henry Schmitz (Chicago): I am not going to discuss the physicists' papers. A busy clinician must take their measurements and conclusions as correct and translate them into his technic of radiation therapy.

The outstanding facts in the paper of Dr. Weatherwax and Dr. Widmann are that in application of the X-ray dose, four factors must be observed: (1) the careful standardization of the output of the tube; (2) the careful study of the anatomic cross-section; (3) the use of equal intensity curves in the calculation of the X-ray doses delivered through multiple fields, and (4) the employment of the saturation method of Pfahler.

The history of "equal intensity curves" recalls to my mind the pioneer work of Friedrich, who, in co-operation with Dr. Glasser, was the first one to measure and publish equal intensity curves. Modern radiation therapy was thereby placed on a scientific standard and I am happy to give these men credit for what they have initiated in X-ray therapy. The labors of Dessauer, Glocker, Duane, Bachem, Erskine amongst others must also be mentioned in this connection.

The X-ray therapist should be thoroughly familiar with this work in order to give the patient the best possible chance from a correctly applied technic of radiations.

A valuable recent contribution to radiation therapy has been the work by Pfahler which was initiated by Kingery, on the so-called saturation method.

Those who have been doing interval radiations and have been applying the summa-

tion of a 100 per cent erythema skin dose probably have remained below the maximum full dose that could be applied using the saturation method.

Widmann and Weatherwax have demonstrated that a 25 per cent dose given every other day permits a saturation dose of 150 per cent. That is, six times the 25 per cent dose will give the same skin reaction as from the radiation with one full dose. This is due to the fact that with the interval method the tissues have a chance to react and recover from some of the action caused by the radiation. Therefore it becomes necessary, in order to get the fullest effect of the radiation, to saturate or add additional dosage to the treatment.

Another benefit derived from the saturation method is that the reactions are never as severe as with one full dose. Should the patient possess an idiosyncrasy or react poorly to radiations, then the treatment may be interrupted until such time as the patient has overcome the untoward effects from the small doses. It has also seemed to me that the smaller doses, repeated at stated intervals until saturation has been attained, are borne much better by the patient.

Dr. A. W. Erskine (Cedar Rapids, Iowa): These papers and the other papers which have been read during the meeting on the r-unit have shown, I believe, that the r-unit is at least sufficiently accurate so that it should come into general use by practising roentgenologists. I think there is no doubt but that the relative accuracy of the r-unit is much greater than any definition of a biological reaction, such as the erythema, can possibly be, and it seems to me that many of the apparent differences are not differences in the r-unit at all but are different conceptions of what the definition of the erythema should be. In other words, I am convinced that 750 r-units of a certain quality expresses much more accurately a certain dose of radiation than can be expressed in terms of redness and scaling and epilation and all of the other things that we see in what we speak of as the "average erythema" or "threshold erythema" or a "good erythema." I think we should discard these indefinite terms.

Dr. G. Failla (New York): Referring first to the paper presented by Dr. Weatherwax and Dr. Widmann, I wish to point out that the chief value of this contribution resides in the method used for estimating and recording radiation "doses" within the irradiated tissues. Correlation of cause and effect (radiation dose and clinical result) is impossible unless one has a fairly quantitative knowledge of the cause. The method outlined in the paper under discussion provides a permanent record of the dosage distribution both as regards space and time, and enables the radiologist to interpret more intelligently the results obtained. It should be noted that the method of estimating and recording dosage is absolutely independent of the particular technic employed. It is presented here in connection with the "saturation method" procedure, but it should be used no matter what mode of treatment is followed.

When it comes to the merits of the saturation method, there is room for disagreement. Whether better results are obtained by this method than by another depends on many factors, but in particular it depends on the possible modification of the relative sensitivity of normal and pathological tissues. It is evident that a much larger dose may be administered to the skin if the treatments are divided over a period of weeks than if a single treatment is given. This means that the skin is more "resistant" to the divided treatments than to the single treatment. However, it may well be that the tumor is equally resistant to the divided treatment and, therefore, it is not affected to a greater degree by this treatment than by a single irradiation of smaller amount. *If*

this is the case, there is no choice between the two as far as the criterion of tissue sensitivity is concerned. There are, however, other criteria, such as the systemic effect on the patient, etc., which must be considered also. The problem is very complex and can be solved only by careful observations extending over a long period of time. Accordingly the authors are to be congratulated for the painstaking way in which they are studying the problem.

I should like to bring out the difference between the saturation dose and the fractional dose methods. In the latter case the treatments, spread over a period of time, are all of approximately the same magnitude. In the saturation dose method, the initial treatment is large, so as to deliver an erythema or suberythema dose to the patient at one sitting, and subsequent treatments are small, with the idea of compensating for the "loss of effect" during the time interval. Dr. Regaud, of Paris, who is the chief exponent of the fractional dose method in radiotherapy, claims that the tumor cell, dividing more rapidly than the normal cell, is more apt to be caught at its most sensitive stage when the repeated small doses are administered at short intervals. On this basis, therefore, a more marked effect should be produced in the pathological tissue than in the normal tissue by the fractional dose technic. The saturation dose method might be considered to be a combination of the massive and fractional dose methods. As already stated, the best method can be determined only by careful comparisons in which all factors are taken into account.

Referring to the paper by Dr. Hickey and his collaborators, I should like to point out that the authors state the type of machine, the voltage, the filter, and the effective wave length of the radiation they used. Accordingly the quality of the radiation they used is definitely specified for practical purposes. As I have mentioned before, the effective wave length alone would not suffice. But in connection with the other three factors it is just as satisfactory as the half value layer or the absorption coefficient.

In regard to the measurement of erythema I have had no experience, either directly or indirectly, with the method employed by the authors, and I do not know just how reliable it is. However, it seems that they have taken sufficient precautions in determining both the amounts of radiation used and the degrees of erythema produced, to warrant some definite conclusions. Personally I should prefer, for the determination of equality of effect, the threshold erythema scheme used by Mrs. Quimby at the Memorial Hospital for many years. With this method it is not necessary to estimate the degree of erythema but it suffices to know whether an erythema is or is not present. The great disadvantage of this method is that a large number of tests must be made in order to get conclusive results. On the other hand, the results are more reliable than can be obtained by any other method of which I know. I should like to see the present work checked by such a procedure.

Listening to this paper, as read by Dr. Barnes, I was impressed by the conservative way in which the conclusions were presented. I feel that the avoidance of sweeping statements in scientific papers is very laudable.

The paper by Dr. Glasser and Dr. Portmann tends to create the impression that the same number of r-units of radiation of any type from beta rays to gamma rays, including X-rays of any quality, will produce the same skin effect. If this is not the inference, I fail to see what is meant by "the reliability of the r-unit."

Aside from the question of quality, which is still unsettled, it is certain that the time element of the dose has a large influence on the biological effect, and this is lost sight of when the quantity of radiation is expressed in r-units. Dr. Weatherwax has shown, for instance, that with the saturation method

one can administer two or three erythema doses over a period of a few weeks. I feel, therefore, that it is desirable to emphasize the limitations of the r-unit to avoid unpleasant, if not disastrous, consequences from incorrect interpretations of its relation to biological effects.

In regard to the reported agreement of the experimental determinations of the r-unit made in this country and in Germany, I said yesterday that if such agreement exists it is probably accidental and in any case it is not significant. I take this opportunity to explain this further. We all know that for quite a period of time Dr. Glasser found considerable discrepancies among instruments made and calibrated in Germany, and also with respect to his own instrument. Then Behnken came to this country, compared his instrument with Glasser's and Duane's, and reported a substantial agreement among the three. In the meantime, Glasser had added a certain diaphragm to the X-ray tube to cut out "the stem radiation" and this made a considerable difference in the determination of the r-unit.

My work with many different combinations of diaphragms has shown also that the magnitude of the r-unit depends to a considerable extent on the diaphragm system employed. Therefore, there can be no agreement unless different experimenters employ identical, or at least equivalent, diaphragm systems. Since two of the authors mentioned above (Glasser and Duane) have not described fully their diaphragm systems, which, incidentally, are quite different, the agreement among the three must be purely accidental.

Now if we agree on a system of diaphragms to be used for the determination of the r-unit, there will be no serious discrepancies. Nevertheless, there may still be a considerable difference between the r-unit as defined and the r-unit as determined experimentally with an arbitrary system of diaphragms. We may illustrate this by an analogy. Let us say that the definition of the unit of length—the foot—is the average length of the feet of the adult male population of a certain town, at a given time. Before the unit is established by actual measurement I can take the length of my foot as my own unit, and my neighbor can do likewise. The two may agree by accident, or by mutual consent we may adopt the same unit. There is no reason to suppose, however, that our unit will agree with the one which will eventually be adopted when the feet of all the adult males in the town have been measured.

The question of the r-unit reduces simply to this: There can be no international r-unit until there is an international standard instrument to determine the unit with. There can be no international standard instrument until certain problems pertaining to the design of such an instrument have been solved. Since no international agreement on this question will be reached until the next radiological congress, we may in the meantime adopt a national standard, so that instruments may be calibrated. It is desirable, however, that such an instrument be designed in such a way as to avoid large discrepancies between the temporary national unit and the ultimate international unit. For this reason it is preferable to wait until the Bureau of Standards will have developed an instrument which meets the necessary requirements before the r-unit is put into general use.

There is at present too much indiscriminate calibration of machines in so-called r-units, and the agreement is not very good. Furthermore, the calibration of a machine is practically useless unless the radiologist has a simple and reliable instrument which he can use to check the output from day to day.

It is difficult at present to compare treatments given by different radiologists for

lack of a common unit. Let us not, however, rush into the use of such a unit before we are properly equipped, both physically and technically. If we do so we shall find that treatments which are identical "on paper" are really quite different, because the various radiologists did not use the same r-unit or the same beam of radiation which was originally measured in r-units per minute.

DR. E. LORENZ (Cambridge, Mass.): I wish to make only a general remark about these papers, as almost everything that is to be said has already been mentioned by Dr. Erskine or Dr. Failla.

Dr. Glasser and his colleague have proved again that the r-unit, as defined by Behnken, and his own agree very well within the experimental errors. Further, Dr. Hickey and his collaborators have shown that the small ionization chamber, if properly checked, is reliable for dosage measurements in r-units. Therefore, I think, these questions are settled now, and the roentgenologist can use the r-unit for his practical work.

However, this does not mean that the matter is settled for the physicist; still many questions have to be investigated and I acknowledge the difficulties Dr. Failla mentioned. But this has nothing to do with the use of the r-unit for practical purposes.

DR. H. J. ULLMANN (Santa Barbara, Calif.): I am going to make a statement which, I believe, will be correct, regardless of what per cent loss per day we finally determine the tissue to lose; whether we assume it to be between the 5 and 6 per cent of Dr. Weatherwax and Dr. Pfahler or the 8 per cent per day loss in the skin as determined by Dr. Stenström. My only assumption is that there is such a loss.

It is necessary to take the order in which the ports are given into consideration when calculating depth dose, and it also makes the method of Dr. Weatherwax of great importance—the method of giving all the ports at the same time. If this be done, the order of ports may be ignored. If one does not give them all at the same time, one must determine the order, and the optimum order is giving those ports first which give the least depth dose. If this is not done, there will be a much larger dose on the skin in relation to the depth dose. I brought this out at Kansas City and it will be published in the *American Journal of Roentgenology and Radium Therapy.*

There is also another factor which will apply even when giving all the ports at the same sitting. There is a definite optimum fraction for a definite depth dose; at one depth the optimum may be 25 per cent per day; at another depth the optimum may be 30 per cent. I have no data as to which of these is correct: it must be figured out for the per cent loss that that worker assumes. It is a factor that must be taken into consideration.

I would like to ask Dr. Barnes why it would not be of more value in such a report as he has made if the r-unit reading had been taken with the chamber on the patient so as to include the back-scattering. That is something we must take into consideration in clinical work.

DR. BARNES (closing): We determined both—primary energy in the air and then determined the actual amount on the skin of the patient. The difference with these field sizes is negligible.

DR. GLASSER (closing): We have listened to a very valuable group of papers on dosimetry, those presented this afternoon as well as those presented yesterday [papers of Dr. Wood, Dr. Failla, Dr. Stenström, and Dr. Quimby]. I think that we all have the impression now that the dosage

problems have been pretty well worked out within the last few years, and that we actually have reached a point where we at least have something practical to show. We all know that there is still room for improvement in more than one respect, but the papers presented have shown that we have a rather solid foundation on which to build further. A few points are under discussion, most of which, however, have already been well taken up by Dr. Failla.

It seems to be the general consensus of opinion that the quality of the radiation beam is preferably determined and given in effective wave lengths, following the suggestion of Prof. Duane. To avoid difficulties and causes for error, it is, therefore, advisable to hold to this quality indication in our work, even if we feel that one or the other of the various other methods may be superior to the effective wave length method. In this connection I would like to ask Dr. Mutscheller (unfortunately I could not hear his paper very well) just what is the degree of difference in the concrete results under given experimental conditions as obtained by his method of the average wave length and by Duane's method of the effective wave length, and whether or not he considers that difference sufficiently large to cause him to have a decided preference for his method.

Dr. Taylor's paper on the dosage unit for cathode radiation is very valuable and probably will be extremely welcome just now when we are about to start using the cathode rays on a larger scale. I wish to ask Dr. Taylor whether he thinks that there is a possibility of interlinking the r-unit with the dosage unit for cathode rays.

I was surprised to hear that Dr. Weatherwax still uses about 1,400 r-units, as measured on the patient, for his erythema dose. According to our recent experience this seems to be rather high. We went down to from 800 to 900 "r," as measured on the patient, a value which seems to be quite in agreement with the values of Dr. Hickey and Dr. Pohle. This paper, by the way, eliminates a point of discussion between Dr. Pohle and ourselves. The paper of these authors and their collaborators, as well as the one by Dr. Burby, presents numerous valuable data. They certainly have done a large amount of work on quantity and quality measurements of X-rays, checking one method against the other, etc. They also brought out the point that giving the effective wave length seems to be the most satisfactory method of quality indication. Their presentation of intensity data of rectifier and valve tube machines proves the superiority of the latter, but I wonder whether I understood correctly—I understood them to say that for equal effective wave lengths the output of the valve tube machine is about 80 per cent higher than that of the rectifier type.

Dr. Failla, who said that he would be pessimistic again, was not pessimistic after all; his pessimism is stimulating. Often we get more stimulation from an apparent disagreement than if we agree all the time. He must have misunderstood the part of our paper on the reliability of the r-unit; in this paper we did not speak at all about the erythema dose but mentioned only the physical dose measurements in air. We know that in our paper there are some points open for discussion, as, for instance, the measurement of the beta rays of radium in r-units, but I feel that in general the reliability of the r-unit has been well proved in its use in roentgen and radium therapy.

DR. A. MUTSCHELLER (Long Island City, N. Y.): I am glad that the question asked by Dr. Glasser came up for discussion. As I recollect, it is whether there is a difference between the effective and the average wave lengths, and how much it is. The differ-

ences between the numerical values are quite considerable and they are due, in the first place, to the fact, in the case of the effective wave length, that the slope of a sector of a curve is measured, whereas, in the case of the average wave length, the slope of a real tangent is measured, which, of course, would give rise to considerable numerical differences.

In the second place, however, if one determines only two points and draws a line through them, then the possibilities of error are so great, especially since we have to consider absorption measurements by ionization, that they are hardly accurate enough to be depended upon alone. It is very much better to measure several points; in other words, to make an absorption curve and then the various points balance their errors against one another and give a dependable result.

But I have intentionally omitted to compare the two methods directly for the following reason. Some time ago I had a conference with Professor Duane on the subject and I believe that in most parts he agreed with my explanations. There are, however, still a few more points that I would like first to talk over with Professor Duane before I talk about them in public. These points are entirely on the practical method of carrying out the measurement. However, I would like to repeat again that there is no difference whatever in the theoretical foundation of the two methods, and I believe it is more or less a question of estimating the practical utility of each method and the degree of accuracy obtainable with each in order to reach a decision as to whether the effective or the average wave length method should be adapted.

If I remember correctly, Dr. Glasser mentioned that the output from a constant potential machine as compared with that of a mechanical rectifier is of the ratio of 123 to 300 in time. This might give the wrong impression if it is not also mentioned that the milliamperage was either 4 or 5 for the constant potential and 25 for the mechanical rectifier. Calculating this out brings the ratio as that found by others, namely, as 1 : 2.

Still another point mentioned by Dr. Barnes is liable to create a wrong impression. He concluded that the half value layer method gives numerical values in proportion to the depth doses obtained. If I am not mistaken, however, the table in question gives half value layers in one case measured in copper and in the other in aluminum, and then, naturally, two different voltages might give the same half value layer and proportional methods in depth doses, which is merely a coincidence and not a general relation. This is simply for the reason that 180 K.V. filtered through aluminum and 180 K.V. filtered through copper do not produce the same radiation in spite of the fact that their half value layer values may be the same.

The average wave length, however, brings out this fact and, as I showed in my paper, a given radiation filtered through copper gives a different average wave length than one filtered through aluminum. In other words, 180 K.V. filtered through aluminum may be a very similar radiation to 80 K.V. filtered through copper. I believe, though, that the contention of Dr. Barnes is based on an accident, and if he looks again into these matters it will rather disprove his contention and it will turn out to be a further argument in favor of either the effective or average wave length methods.

DR. TAYLOR (closing): Just to say one word in answer to Dr. Glasser's question: It is not apparent, looking at it from the first sight, that you can measure the cathode rays using the same unit as X-rays. The process is slightly different; in fact, considerably different.

The X-rays pass through air and knock out some photo-electrons from the air mole-

cules. The photo-electrons wander around and produce positive and negative ions and you measure those ions.

In the case of the cathode rays you are dealing with electrons directly. In other words, you are dealing with the third stage process in the case of the r-unit and X-rays, and you are dealing with first stage process in measuring electrons.

Also in measuring cathode rays considerable care has to be taken that you do not include in that measurement any of the effect due to the ionization of the air produced by the electrons. You must single out positive and negative ions and measure only electrons and make proper correction for the positive and negative ions which impinge on the collector plate. So it is not quite apparent, at least at the present, that you can use the same definition for a unit or same type of system for measuring the cathode rays and X-rays.

DR. WEATHERWAX (closing): I want to say a few words regarding the erythema dose which we have represented as 970 r-units. We are simply stating the erythema dose we are using and not advocating the same as a standard. (Mechanically rectified equipment, water-cooled X-ray tube: our erythema value is 300 ma.-mins., 50 cms. S.T.D., ½ mm. of Cu. and 2 Al. as filters, 200 K.V. peak, and a field 20 cms. in diameter.) This value may have a variation of about 8 to 10 per cent, because I calibrated a Wulf Ionometer with Dr. Mutscheller some time ago and found about 20 per cent discrepancy between the calibration I had from Germany of the Wulf Ionometer and the measurement that Dr. Mutscheller had made with Dr. Duane only two or three weeks previously.[1]

I assumed that the German calibration was wrong and took the calibration I made with Dr. Mutscheller. I am going to make some more standardization measurements of my own apparatus to determine definitely whether there is a discrepancy.

As far as the use of the saturation method of treatment is concerned, we are not so sure ourselves that the curve that Dr. Pfahler has suggested for deep therapy represents the biological changes on the skin, but we are following the curve as a guide, or as a standard, or something that we can tie up our records to in a tangible way so that we can represent our dosage, with time, graphically.

I am sorry I am unable to give you more of the clinical side. I am sorry Dr. Widmann could not be here to discuss this paper, because I am unable to discuss the clinical aspects of our treatment, but we are, I think, getting much better results now than we have ever gotten before. We have used the saturation method for about a year and a half. We started our deep therapy using a massive dose technic and then we followed along for a couple of years using the small dose technic, extending over a long period of time, and now we are using the saturation technic.

It may be that we are more vigorously treating our tumor areas to-day than we were three or four years ago, and that may be the reason—or partially the reason—why we are apparently getting better results to-day than we ever did before. However, we wish to emphasize that whatever our technic may be, a careful record, with time, should be kept.

DR. POHLE (closing): I am very glad to state, as I take it from the discussion this afternoon, that we evidently all agree on the principal points in the argument, and particularly on a desirable method of defining quality which is accurate enough for practical requirements.

In our paper, we suggested the effective wave length of Duane because it requires only the taking of two readings and you will

[1] A calibration in January, 1929, checked the German calibration. This gives us an erythema value of 800 r-units as measured in air.

all agree with me that the simpler the method we adopt for practical use in the X-ray laboratory, the more chance we have to see it carried out in many places.

As far as the relation between r-unit, wave length, and toleration doses or erythema doses is concerned, I think that to-day we have gone a great step forward. For small fields, it seems permissible to use the same number of r-units throughout the wave lengths examined, and for large fields, we would not advise the use of this principle for the reason that there is no exact method of measuring the back-scattering on the patient. It is quite possible to measure the amount of back-scattering in a water phantom by putting a small enough chamber of the proper wall material in the proper position, but, as far as I can see, the results are not transferable, without correction, to the patient.

Discrepancies, such as have come up during the past year, are bound to arise in a field which grows as rapidly as this field of X-ray therapy does. However, it seems to me the few differences we still have can be straightened out as we go along, and the more we learn about this subject, the better we will understand each other.

Dr. Portmann (closing).: I have just a word or two in closing. Dr. Glasser remarked that we said nothing in our paper about biological effects. Previously, however, we reported some biological effects of radium as they seem to differ from those of X-rays.

That 1,600 r-units with radium give the threshold erythema of Quimby and Quick is apparent.

Now as to this matter of the erythema, I wish that we might get rid of the phrase "erythema reaction." It does not mean a thing and the sooner we cease expressing biological reactions in the terms of reddening of the skin, the better off we are going to be.

I think that the paper presented by Dr. Barnes was particularly fine at this time, and I think Dr. Pohle's discussion of the paper was particularly illuminating. It clears the atmosphere very beautifully, very much to the satisfaction of some of us poor therapists who cannot get away with all of the physics that we should like to. We have demanded a unit for the physical measurement of X-rays and the physicists have given us what we wanted although they have left a loophole through which they can crawl later on. There is no reason why we should not adopt it and go ahead and do our work with the unit which they themselves have provided, and let them provide something else some other time. I hope that this will be a long while in the future.

THE MEASUREMENT AND SPECIFICATION OF RADIANT ENERGY[1]

By HENRY LAURENS, PH.D., and H. S. MAYERSON, PH.D.
From the Laboratory of Physiology, School of Medicine, Tulane University, NEW ORLEANS, LOUISIANA

NO one who uses radiant energy, solar or artificial, for therapeutic or experimental purposes will question the necessity of measuring and specifying it. Personally we feel that the specifications should be in absolute units, the erg or the calorie, and since the methods permitting this are no more difficult than those giving results expressible only in arbitrary units, there is no valid reason why such methods should not be used universally.

The radiations from artificial sources admittedly represent but approximations to sunlight, and no two sources are alike in respect to the spectral distribution of the energy they emit. This is the physical reason why different sources can not produce the same therapeutic or biological action. We are not so much interested in making comparisons between the energy emitted by different sources, and their biological or therapeutic action, as in knowing that the energy is different and that we do not speak of the energy emitted by this, that, or the other lamp as representing "artificial sunlight" when it is as far from that as it can possibly be. The use of radiant energy for therapeutic or scientific purposes must be built on a strong foundation of physics, and, if we are trying to imitate sunlight, it behooves us to know something not only about the physics of sunlight, but about the radiation of artificial sources as well. In recent reviews (Laurens, 1928) brief résumés are given of the differences between the characteristics of the energy emitted by various sources, as well as of the various methods for measuring solar and artificial radiant energy.

Choice of Source.—Of available sources the sun, the Hg arc in quartz, and the C arc burning solid or cored carbons filled with mixtures of rare earths are the only ones of practical importance, though iron arcs and tungsten arcs have also been used in experimental work. The kind of problem or the nature of the clinical condition should determine the particular source selected. There is a common belief that the radiation of such sources is solely or mainly active because of the ultra-violet fraction. This is so in some conditions but it has been actually demonstrated in very few instances, and there is much evidence that the effects observed are also due to luminous and infrared rays, either *per se* or by their action in increasing the effect of the ultra-violet. In general, it seems that if artificial radiant energy be used, one should choose a source which emits, like the sun, a continuous spectrum, possessing much blue, violet and ultra-violet of not too short wave length, as well as luminous and heat rays (Strandberg, 1928).

Nature of Spectra.—The sun's spectrum (Fig. 1) is continuous except for the shadows of the dark Frauenhofer lines. The short wave length limit is 290 mμ (at high altitude in July), while the longest are about 5 μ, although there is very little energy beyond 2 μ. Solar radiation is often described as extending from 0.3 μ to 3 μ. Most artificial sources emit shorter and longer wave lengths, some both, others one or the other.

The spectrum of the ordinary C arc shows a groundwork of a mass of fine lines with bright lines from the spectrum of the various impurities in the carbons, especially Fe and Ca. The white flame C arc spectrum (Fig. 1) consists essentially of two,

[1]Aided by a grant from the David Trautman Schwartz Research Fund.

a line spectrum from the metals added to the carbon—the radiation of the arc vapors—upon which is superimposed the continuous spectrum of the incandescent positive crater. The spectrum extends in the ultra-violet to 218 mμ, though most of the energy is at wave lengths longer than 300 mμ, to the neighborhood of 6 μ in the infra-red.

The spectrum of the Hg vapor lamp in quartz (Fig. 1) is discontinuous (strong emission lines on a background of a weak continuous spectrum), the shortest lines getting through the quartz and air being 185 mμ. Between this and 290 mμ there are a number of weak lines. Between the powerful group of lines at 365 mμ and the double line at 313 mμ there is but one strong group at 334 mμ. There is a powerful line at 579 mμ, a slightly weaker one at 540 mμ, and another at 436 mμ. There are lines in the infra-red in the neighborhood of 1, 1.3, 1.4, and 1.8 μ, besides the longer waved radiation emitted by the heated electrodes and hood or reflector.

The Fe arc spectrum (Fig. 1) is an intense and rich line spectrum, fairly continuous to about 230 mμ, though extending to shorter wave lengths than this.

Methods of Measurement.—Various methods are available for measuring and specifying the total amount of energy emitted by a source, as well as its spectral distribution. These may artificially be divided into two kinds:

(1) Those designed for rapid and easy use and which make use of biological or photo-chemical reactions to determine the entire ultra-violet component, or a portion of it. These, because of their rapidity and ease of manipulation, are regarded by many as sufficiently accurate for clinical use, but

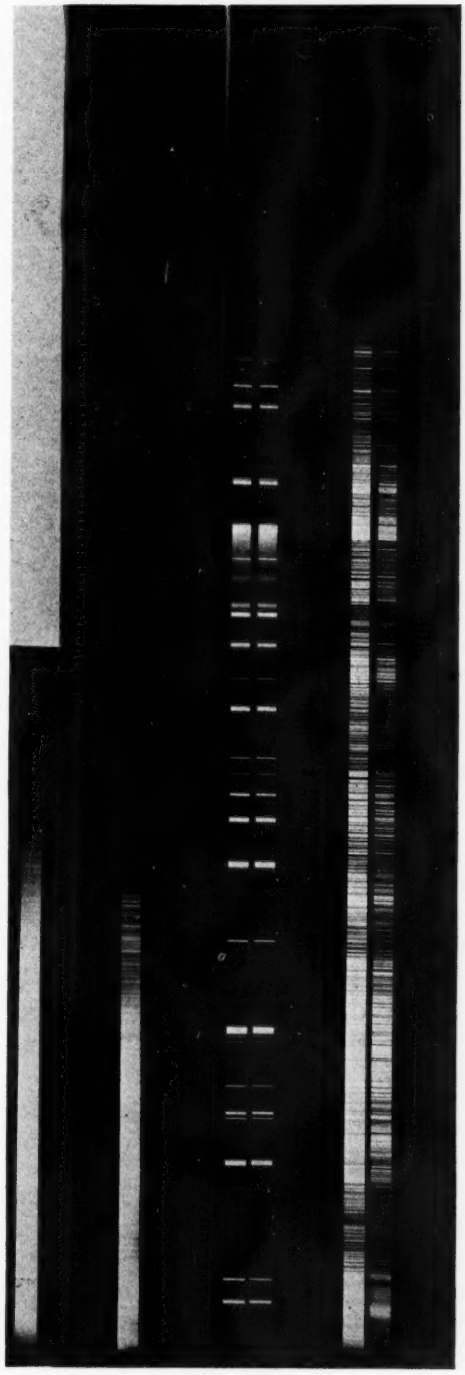

Fig. 1. The first pair of spectrograms are of the iron arc (6 A, 35 V), exposures of 20 and 60 seconds, respectively. The second pair are of the Hg arc in quartz (5 A, 70 V), exposures of 2 and 5 seconds. The next, single, spectrogram is of the flaming C arc (28 A, 60 V), exposure of 5 seconds. The bottom spectrogram is of the sun taken on May 24, 1928, at 11 A. M., exposure of 15 seconds.

they merely gauge the gross intensity of total or of shorter waved ultra-violet present and give no information regarding the relative intensity of the wave lengths in that region.

(2) Those employing accurate physical methods. Of these, there are three of interest in the present connection, respectively involving (*a*) thermo-electric measurements (radiometry), (*b*) chemical reactions (including photometry by photography), and (*c*) discharge of electrons. The general methods are briefly described in the reviews referred to above.

Photo-electric cells are selective in their response but may be employed from beyond the visible red into the far ultra-violet. Their response to light is immediate, with no measurable "lag," and the magnitude of the photo-electric current, in a properly designed cell, is directly proportional to the intensity of the exciting radiations. Pohle and Huxford (1928) have recently described the characteristics of the cadmium cell, which is highly selective. Of lesser importance are devices which experience a change in resistance upon illumination. The most sensitive of these are selenium, cuprous oxide, and thalofide cells. The spectral response is highly selective and all reveal "lag" to a greater or less degree (Pfund, 1927).

Radiometry.—Radiometry is the "élite method" for measuring radiant energy. It involves the measurement of the heat produced when radiation is absorbed, the intensity being expressed quantitatively as the number of calories, or ergs, of heat produced per unit area of absorbing material. Radiometers are non-selective, having blackened receiving areas. In consequence, all energy, regardless of wave length, is absorbed and transformed into heat. The response of non-selective receivers is directly proportional to the intensity of the incident radiation because, for the small rise in temperature involved, the thermal E.M.F. generated is directly proportional to the heat generated, which, in turn, is directly proportional to the energy absorbed. Absolute values of the intensity of radiation may be obtained by resorting to the use of standardized incandescent lamps. Such lamps are operated at a defined voltage or current, and the intensity of the total radiation at a fixed distance in a definite direction is known to a high degree of accuracy.

Our radiometer consists of a Hilger linear thermopile, a high sensitivity galvanometer and auxiliary apparatus. In order to convert the responses of the thermopile to C.G.S. units, the thermopile is calibrated against a radiation standard. We use a "thoroughly seasoned" carbon lamp, obtained from the Bureau of Standards, Washington, the radiation from which is evaluated in terms of the primary standard conserved at the Bureau. Since any such standard deteriorates with use, it is used merely as a reference standard, another lamp calibrated by us against the Bureau of Standards lamp being used as a working standard.

The standard lamp screwed into an ordinary socket is connected in circuit with an ammeter and a variable resistance which is adjusted so that the lamp consumes 0.4 ampere, under which conditions the thermal radiation flux at 2 meters distance is 82.5×10^{-8} watt per sq. millimeter. An opaque cardboard shield, 1 meter $\times$ 1 meter, with an opening 10×15 centimeters, is 25 centimeters in front of the lamp. A black shutter (20×20 centimeters) covers the opening in the shield. The thermopile, connected with the galvanometer, faces the opening in the shield at a distance of 2 meters from the lamp. A black cloth screen 1 meter $\times$ 1 meter and 1 meter to the rear of the lamp prevents reflection of radiation from the wall. Figure 2 shows the set-up.

Since the galvanometer sensitivity may

vary from time to time, it is necessary to establish for it a standard of sensitivity and to reckon the radiation sensitivity of the apparatus in terms of the reading at this standard sensitivity. In order to use the value so obtained in future work with the apparatus, it is necessary each working day to determine the current sensitivity of the galvanometer and to compute from this and the standard sensitivity a correction factor which has to be applied to all readings taken at this particular time.

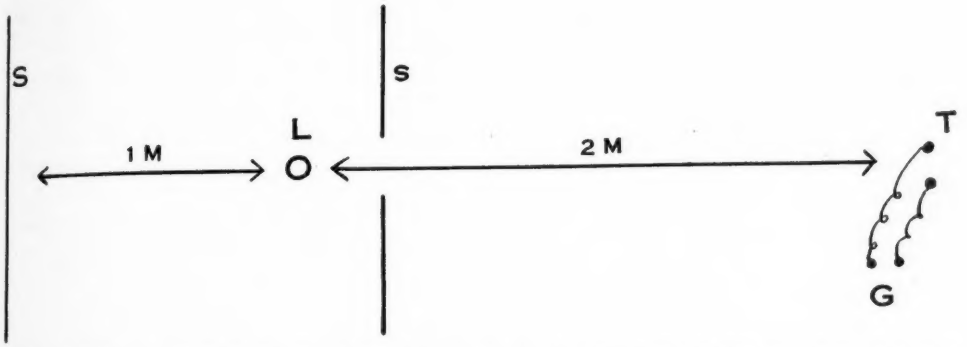

Fig. 2. Diagram of Radiation Standard set-up. L = standard lamp (0.4 A, 91.9 V). S = black cloth screen 1 meter square. s = black cardboard screen 1 meter square, with 10 × 15 cm. opening. T = thermopile. G = galvanometer.

The apparatus for determining the sensitivity of the galvanometer consists merely of a dry cell, giving an E.M.F. of known voltage, and appropriate resistance. The amount of current passing through the galvanometer divided by the number of scale divisions of deflections gives the value of the current required to give a deflection of one scale division, or the sensitivity of the instrument. For example, if a galvanometric deflection of 56 centimeters is produced by a current strength of 1×10^{-7} amperes, the amount of current necessary to give a deflection of 1 mm. is 1.8×10^{-10} amperes. This, then, is the standard current sensitivity of the galvanometer.

The radiometer (thermopile and galvanometer) must also be calibrated. The specification of the sensitivity of a thermopile in terms of microvolts per microwatt of radiant power, or a similar notation, is not complete (Coblentz, 1914). But it is sufficient, after specifying the current sensitivity of the galvanometer, to state the deflection produced per microwatt of radiant power incident upon a receiver of specified area. In this manner the thermopile serves merely as an intermediary in comparing the intensity of unknown radiant energy with that of a standard of radiation.

The total amount of energy falling on the thermopile is determined by multiplying the radiation per sq. mm. at 2 meters by the area of the thermopile's receiving surface. Taking the deflections of the galvanometer, in terms of sensitivity, and the total amount of energy falling on the thermopile, the amount of energy to give a galvanometric deflection of 1 mm. is determined. This is a measure of the sensitivity of the radiometer.

The sensitive area of our thermopile is 20×1.5 mm., that is, 30 sq. mm. or 0.3 sq. cm. Since the radiation intensity of the standard lamp at 2 meters is 82.5×10^{-8} watts per sq. mm., the total energy falling on the thermopile is $2{,}475 \times 10^{-8}$ watts. In one set of readings this amount of radia-

tion produced an average galvanometric deflection of 126 mm., whence 1 mm. deflection $= 19.6 \times 10^{-8}$ watts, or 1 mm. deflection $= \frac{100}{30} \times 19.6 \times 10^{-8}$ watts, or 6.53×10^{-7} watts, per sq. cm. Since 1 watt $= \frac{10^7 \text{ ergs}}{\text{sec.}}$, and since 1 erg $= \frac{1 \text{ g. cal.}}{4.185 \times 10^7}$, therefore 1 watt $= \frac{1 \text{ g. cal.}}{4.185 \text{ sec.}}$. And since a 1 mm. galvanometer deflection is produced by a radiant flux of 6.53×10^{-7} watts per sq. cm., therefore 1 mm. deflection is produced by $\frac{6.53 \times 10^{-7}}{4.185}$ g. cal. per sq. cm. per sec., or 1.56×10^{-7} g. cal. per sq. cm. per sec. This is the sensitivity of the radiometer (galvanometer and thermopile).

A galvanometer deflection of 1 scale division representing a known energy flux has definite absolute value. Multiplying the observed galvanometer deflection produced by the radiation from the source being measured, and knowing the distance intervening between the source and thermopile, it is possible to specify the intensity of the energy or radiant flux incident at the point where the measurements are made in gram calories per sq. cm. per sec.

By interposing a screen which absorbs approximately all of the ultra-violet but allows all of the luminous and infra-red energy to pass, and then a screen which similarly absorbs the infra-red, we obtain (after allowing for the reflection and scattering occasioned by the screens) by the method of difference the values of the ultra-violet, the luminous, and the infra-red in percentages of the total.

There are no screens with cut-offs exactly at the boundary between the ultra-violet and the luminous and between the luminous and the infra-red portions of the spectrum. For fulfilling the first purpose we use a Corning Noviol 0, cut-off at 380 mμ, and a Corning Noviol A, cut-off at 410 mμ. For eliminating the infra-red we use, first, a 1 cm. quartz water cell; second, a 2 cm. quartz water cell, and third, a piece of Corning G 392 H in conjunction with a water cell. Points pertaining to the percentage transmission of such screens will be discussed below in the sections devoted to spectroradiometry and spectrophotometry.

In order to offset the effects of the fluctuations undergone by a C arc we alternate between the naked arc and the arc screened, taking the ratio between the two readings. Stockbarger (1926) has described a potentiometer device for use in radiometric work employing filters. To obviate the difficulties occasioned by variations in the intensity of the source, the total radiation falls on one thermopile, the "standard," while the radiation from a smaller spectral region falls on another, the "analyzing" thermopile, the two thermopiles being connected through appropriate potential resistance wires with the same galvanometer.

In our laboratory the percentage distribution of a flaming C arc (25–28 A, 55–60 V, emitting 0.797 g. cal. per sq. cm. per min. incident at a distance of 1 meter) has been found to be: ultra-violet 12, luminous 35, and infra-red 53; that of an Fe arc (6 A, 35 V, emitting at 1 meter 0.0102 g. cal. per sq. cm. per min.): ultra-violet 23, luminous 10, and infra-red 67. The percentage distribution of a Hg arc in quartz (5 A, 70 V) is ultra-violet 30, luminous 50, and infra-red 20.

The flaming C arc (the Pan-Ray-Arc of the Atlas Electric Devices Co.) used by us is very similar, in its percentage energy distribution, to the Macbeth white flame C arc (29 A, 58 V) listed by Coblentz, Dorcas and Hughes (1926), but emits more energy. The Macbeth lamp has a total energy equivalent to 0.66 g. cal. per sq. cm. per min. at 1 meter and an approximate percentage distribution of 13 in the ultra-violet, 29 in the luminous, and 58 in the infra-red.

Variations in the energy input of a lamp result in marked changes in the quantity and quality of the emitted energy. A variation of 5 volts in the line voltage causes a variation of from 13 to 15 per cent in the intensity of the ultra-violet and also of the total output of a quartz Hg lamp (Coblentz, 1921). In a C arc a 5 per cent voltage rise gives 15 to 20 per cent increased emission (Griffith and Taylor, 1928). Accurate control of running conditions is therefore of prime importance if uniformity of dosage is required. If the energy input changes for some reason and can not be brought back to the customary, determinations of the total energy and of its percentage distribution must then be made.

Spectroradiometry.—The use of screens or filters, even when corrections are made for reflection and absorption, to give the percentage values of the ultra-violet, luminous, and infra-red is admittedly only an approximate method, although very convenient and extensively used. Filters to give certain regions of the spectrum minus others may be used when it is not feasible to isolate the desired regions by means of a monochromator. The advantages of filters consist in their simplicity and conservation of energy. They do not, however, afford the analysis possible with a spectrometer. Gibson (1926) gives a very instructive account of the uses and characteristics of filters. To supplement results obtained with them radiation should be dispersed by monochromators or spectrometers having optical parts transparent to ultra-violet and infra-red as well as to luminous energy, and the energy in consecutive narrow bands measured by means of a linear thermopile, placed at the exit slit, connected with a galvanometer. We use a Hilger ultra-violet and visible monochromatic illuminator and a visible and infra-red spectrometer. With these instruments we have determined (1) the distribution of the radiant energy emitted by various sources in the three major divisions (ultra-violet, luminous, and infra-red) as percentages of the total energy ascertained by summing the galvanometric deflections produced by the action of successive bands of energy from one end of the spectrum to the other; (2) the wave length cut-offs, or the limits of transmission at long and short wave lengths, of filters; (3) the wave length percentage transmission of filters (*i.e.*, the percentage of the incident radiation which gets through after the loss suffered by the transmitted rays due to reflection and scattering).

By rotating the prism of the quartz monochromatic illuminator it is possible to direct into the slit of the telescope energy of any wave length of the spectrum from 185 to 806 mμ. The eyepiece of the instrument has a recess into which the thermopile is inserted. The rock-salt infra-red spectrometer is provided with a wave length drum

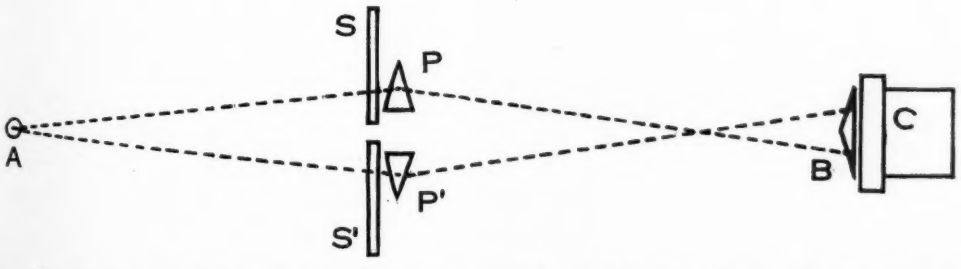

Fig. 3. Diagram of the sector photometer showing pathway of the two beams of radiant energy. A = the source. S = the variable sector. S′ = the fixed sector in front of which is placed the screen or filter. P and P′ = the two quartz wedge lenses. B = the quartz biprism placed in front of the slit of the collimator, C, of the spectrograph.

Fig. 4. A series of 16 double spectrograms taken with the variable sector of the photometer set at different apertures. The numbers at the right are the values for $\log \frac{I}{I'}$, I being the intensity of the incident energy and I' that of the energy transmitted by the screen, in this case a piece of Corning Noviol 0 with a cut-off at 380 mμ.

calibrated from 500 mμ to 10 μ. The thermopile is placed in a symmetrical slit upon which an image of the spectrum is formed. These monochromators give intense spectra of relatively high purity, spectral impurity being chiefly due to scattered radiation caused by the reflection of stray wave lengths, thus introducing an overlapping error. In the instruments used by us this source of error is negligible.

The telescope exit slit is narrowed to 1.5 mm., this being the width of the receiving surface of our thermopile, and a reading taken of the throw of the galvanometer when a beam of energy of certain wave length distribution is allowed to impinge upon the receiving surface of the thermopile. The intensity of the radiation from the monochromator as indicated by the galvanometer deflection is then computed in terms of the deflection produced by exposure of the thermopile to the radiation of the Bureau of Standards certified lamp.

The information concerning the screens is ascertained by comparing the size of the deflections when no screen is present, occasioned by the falling of energy of a certain wave length constitution on the receiving surface of the thermopile, with that produced when the screen is interposed in front of the thermopile.

The spectroradiometric method gives results which are in

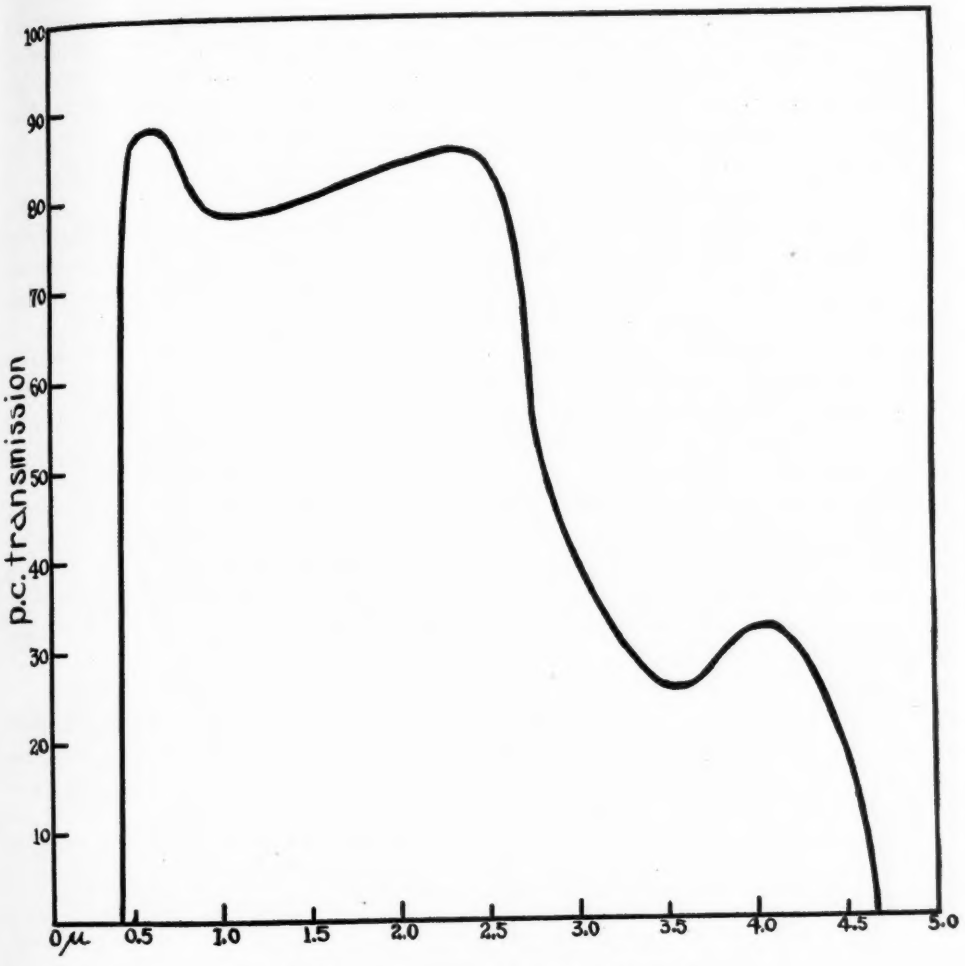

Fig. 5. The transmission of a piece of Noviol 0.

agreement with photographic determinations made with a sector photometer and quartz spectrograph in the ultra-violet and visible (Coblentz, 1928). But, since the photographic method is not readily adapted for measuring the intensity of radiation in the infra-red, only part of which can be photographed by the use of very specially sensitized plates, the radiometric method is really the only one to use in determining the intensity of dispersed infra-red.

Spectrography.—For simply determining the wave length transmission of substances in the ultra-violet and luminous regions of the spectrum, spectrograms are all that are necessary. These give the cut-off in the ultra-violet and qualitatively indicate any absorption at longer wave lengths. Spectrograms, of course, also indicate the general nature of emission spectra (see Fig. 1). We use a large Hilger quartz spectrograph (size E 4) taking 10.2 × 25.4 cm. (4 × 10 inch) plates and giving a dispersion of about 20 cm. between the lines 210 and 800

mμ. As a source we use a Fe arc, the current consumption of which is kept very constant at 5 amperes by an assistant who closely watches the ammeter wired in circuit with variable resistance. The spectrum of iron is probably the most generally useful one. It is intense and fairly continuous to about 230 mμ, and, being a standard spectrum, more and better values are available for it than for any other spectrum of the same extent. It is obvious that for making radiometric or photometric determinations of the spectral transmission of substances in the ultra-violet we must use a source of radiation having a high intensity emission in this region.

The Fe arc used by us is essentially that described by Pfund (1908) and later by Luckiesh (1922) but of special design as to cooling collar and adjustments for varying and maintaining the distance between the poles. The upper pole, which is negative, is a soft Norway iron rod ¼ inch in diameter, surrounded by a well-fitted sleeve of brass turned down to a conical shape at the arc end in order not to obstruct unduly the radiation from the arc. The lower electrode, which is positive, is also a soft Norway iron rod ½ inch in diameter with the end in the form of a shallow cup. A bead of previously molten iron is placed in this cup and when the arc is struck it plays between the bead and the upper electrode, which is well cooled by the brass sleeve, and the arc is steadily maintained between it and the molten bead.

Spectrophotometry.—We use the Hilger sector photometer and the quartz spectrograph. For obtaining values for plotting the transmission curves of substances this photographic method for the ultra-violet and luminous is greatly superior to any other and compares favorably in speed and accuracy with any visual method (Gibson and McNicholas, 1919). It consists essentially in determining at what wave length two contiguous spectra are of equal density; and this value, by this method, is independent of the kind, the law, the chromatic sensitivity, or the length of development of the plate, as well as independent of the kind of developer, the variations in the intensity of the source, and the length of the exposure. The percentage transmission is determined arbitrarily by the ratio of sector openings, the wave length being the dependent variable.

The sector photometer (Fig. 3) consists essentially of two quartz wedge lenses, on one side of which are two rotating sector discs between one of which and the source of energy is placed the screen, cell, etc., the transmission of which is to be ascertained. The quartz spectrograph is Hilger's E 4. A slit width of 0.03 mm. is used. A quartz biprism is placed directly in front of the slit with its refracting edge perpendicular to the slit.

The source of radiant energy is the Fe arc described above. Energy emerging from the arc may reach the slit by two alternative paths. An upper beam passes through the variable sector, then through a quartz lens and wedge, by which it is refracted downwards, and, falling upon the biprism, is deviated by the lower half of it to pass axially along the collimator of the spectrograph. A lower beam traverses a similar path through the filter and the lower sector and wedge lens and is deviated by the upper half of the biprism to pass axially along the collimator like the first.

We thus have the spectrograph fed by two beams from the same source, one capable of being varied in intensity at will by varying the aperture of the rotating sector, the other subject to absorption by the filter. These are dispersed by the quartz prism and a spectrum image of the slit formed on the photographic plate. This spectrum is divided into two halves by a fine line extending along its whole length, which is the

spectrum image of the refracting edge of the biprism. One-half of this spectrum results from the upper beam, the other half from the lower beam.

If the ratio of the upper to the lower sector is unity, and if the arc is in correct alignment, the densities of the two halves will be equal throughout their entire length, thus indicating equal intensity of the two beams. The plate may be raised or lowered in the plane of the spectrum, thus permitting several photographs to be taken on one plate. Both sectors have a maximal opening of 180°.

A series of photographs is taken with the variable sector set to different apertures (Fig. 4). Each of these photographs consists of a pair of spectrum photographs in close juxtaposition, the one which has passed through the filter being more dense than the other in certain parts and less so in others, there being certain wave lengths

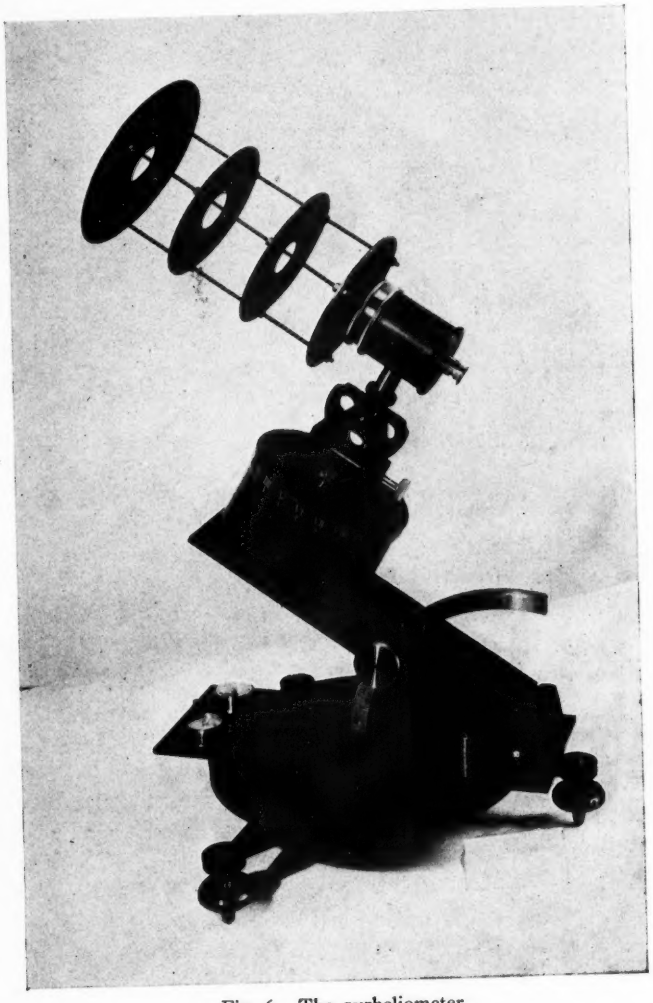

Fig. 6. The pyrheliometer.

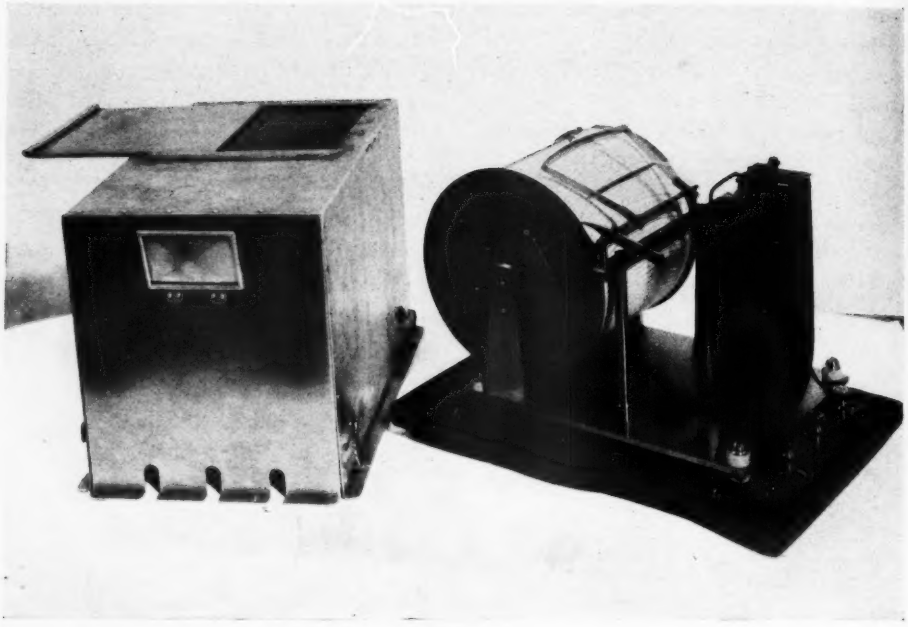

Fig. 7. The recording millivoltmeter which is covered during operation, the movement of the pen being observable through a celluloid window.

where the density of the two is equal. The wave length at which the densities of a pair of spectra are equal is, within wide limits, independent of the exposure, of the intensity, and of the speed of rotation of the sectors. As suggested by the manufacturers we have selected a speed of 120 revolutions per minute. Since the two spectrograms are taken simultaneously there are no errors arising from fluctuations in the source.

The sector is divided to read $\log \frac{I}{I'}$, where I is the intensity of the incident energy and I′ that of the energy transmitted by the medium whose absorption is being measured. If we let the fractions of whole revolutions during which the variable and fixed apertures allow energy to pass be, respectively, T and T′, then $\frac{I}{I'} = \frac{T'}{T}$. Thus, if the wave length of the point where the two spectra are of equal intensity be noted, together with the sector reading, we have all that is necessary for drawing the absorption curve. A table showing the exposures corresponding to the sector openings is furnished with the instrument; the period is the number of which the sector opening is the logarithm multiplied by a constant. The theory of the sector photometer is discussed by Gibson and his coworkers (1922), as well as by the makers in their leaflet describing the method.

The values for percentage transmission obtained by either a radiometric or a photometric method represent the transmission values including the loss due to reflection at the two surfaces. This loss is entirely independent of the transparency of the screen. For example, quartz, which is practically transparent to all radiations, from

extremely short ultra-violet to 4 μ in the infra-red, transmits but 92 per cent at 290 mμ, due to loss by reflection.

There are a number of points which may be cited to show the necessity of making measurements of this sort. (1) If the energy distribution of a source changes, due to variation in power input, the transmission of a screen will also change. Thus it is necessary to determine the transmission in terms of the energy input of the source of energy. (2) In the making of screens manufacturers have difficulty in reproducing the same conditions in different melts, so that the cut-off in the ultra-violet as well as the transmission as to wave length varies in different samples of the same kind of screen. In order to obtain exact data it is necessary to determine these factors on samples from each melt. (3) The drop in the transmission curve in the ultra-violet for screens is not a sharp one, but covers a region of several wave lengths in sweeping from nearly full transmission to absolute cut-off. The limit of transmission ascertained from a spectrogram may thus be a misleading measure of the value of a material for purposes of ultra-violet transparency. A screen transmitting to 270 mμ is likely to absorb a large portion of the energy in the neighborhood of 300 mμ. Spectrophotometric and spectroradiometric determinations of transmission give this information. (4) Of outstanding interest in connection with the transmission of screens, and in particular of some of the recent glass substitutes for quartz, is the fact that the percentage transmission, total and as to wave length, decreases with increasing duration of exposure to sunlight and artificial radiation. Nothing could illustrate more cogently, unless it be a deteriorating Hg lamp, the necessity of constantly making radiometric and photometric measurements to determine the total amount of energy, its spectral distribution, the shortest and longest wave lengths transmitted, and to what extent. (5) When using a screen that has a cut-off, let us say, near the boundary between the ultra-violet and luminous, we must not forget that it probably has a cut-off somewhere in the infra-red. Suppose we have an amber glass, for example a piece of Noviol 0 of the Corning Glass Co., with a cut-off at 380 mμ or thereabouts, everything shorter than this being absorbed, with a typical percentage transmission from here up through the luminous. It is seldom realized that the transmission, though it continues into the infra-red region, eventually markedly and rapidly decreases, so that at about 3500 mμ the glass transmits only 25 per cent of the incident energy. Figure 5 illustrates this point. To disregard this infra-red cut-off will give rise to error in the calculation of the distribution of energy between the ultra-violet, luminous, and infra-red portions of the spectrum, particularly if there is much energy in the infra-red spectrum of the source at longer wave lengths than this. Solar radiation contains not very much, that of the C arc more. As a matter of fact, the infra-red absorption is not much greater for yellow glasses than for white (Sheard, 1928; Coblentz and Emerson, 1919).

Pyrheliometry.—To measure and specify solar and sky radiation we use both a spectrographic and radiometric method. Spectrograms of the sun are made, showing the shortest wave length present for the time of day, season, etc. The pyrheliometer we use is that described by Gorczynski (1924). This pyrheliometer, built by Jules Richard, of Paris, and consisting of a large Moll surface thermopile and a registering millivoltmeter, is a handy, sensitive, and accurate instrument. The exposed surface of the thermopile has a diameter of 20 mm. and is carried on a clock-driven equatorial mounting, which, with a hand-operated altitude and azimuth adjustment, maintains the sur-

face of the thermopile at right angles with the incident rays (Fig. 6).

The recording millivoltmeter (Fig. 7) is first calibrated in millivolts per mm. of deflection and then the pyrheliometer (thermopile and millivoltmeter) is calibrated by exposing it to a known amount of energy, usually a g. cal. per sq. cm. per min. at the distance from the source at which this amount of energy is incident to the thermopile.

By the use of screens as above described, not only is the total amount of energy from the sun determined but its distribution between ultra-violet, luminous, and infra-red as well.

SUMMARY

The essentials of spectroradiometric and spectrophotometric methods are given, together with the reasons as to why radiant energy used for biological or therapeutic purposes should be measured and specified in absolute units.

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ROENTGEN DIAGNOSIS IN GYNECOLOGY[1]

IODIZED OIL AND PNEUMOPERITONEUM COMBINED

By IRVING F. STEIN, M.D., and ROBERT A. ARENS, M.D.
Departments of Gynecology and Radiology, Michael Reese Hospital,
CHICAGO, ILLINOIS

SINCE our presentation of the combined method of pelvic roentgenography before this Society last year, we have continued to utilize the procedure with increased satisfaction.

In order to facilitate this work we have developed a new self-retaining instrument (1) which permits combined intra-uterine insufflation and iodized oil instillation. It also permits the necessary postural changes required for roentgenography, without the usual attendant danger of displacement of instruments, or of back-leakage of iodized oil from the cervix, and obviates the necessity of holding instruments *in situ* with more or less force. We have, likewise, developed a new table useful for roentgenography of patients upon whom this method is employed. The table is simply constructed, is easily handled, and eliminates the use of a complicated arrangement such as has been previously described in the literature. In all other respects our technic is essentially the same as we have previously presented.

As a result of increased experience we have become more cautious of our interpretation of tubal obstruction, and have come to recognize spasm as a definite and frequent phenomenon in normal pelvic viscera. Spasm does not arise in the isthmus of the tube as Kennedy has described, but is initiated in the uterine cornua and is transmitted to the isthmus. Numerous instances of unilateral or bilateral spasm have been registered on the films in which the filling defect is distinctly in the uterine horn. We

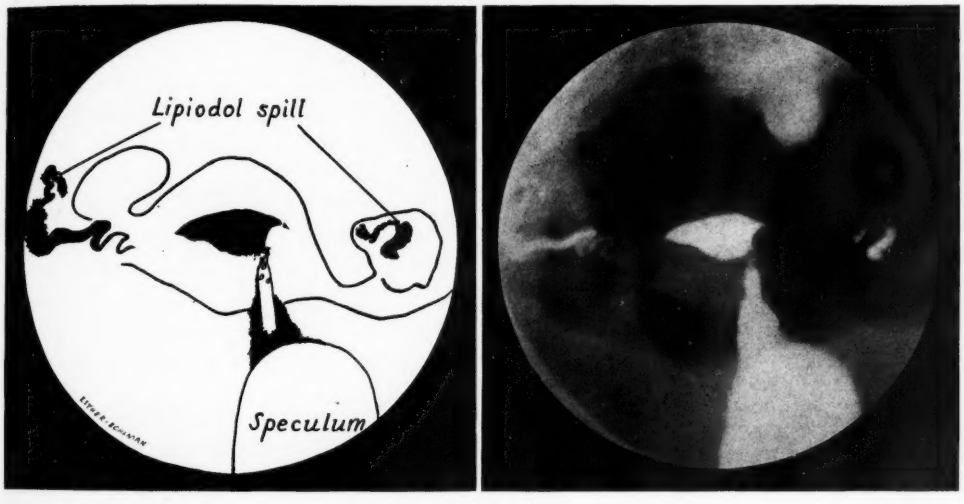

Fig. 1. Secondary sterility: one child six years previous; manual removal of placenta; no pregnancy since; post-coital examination satisfactory. *Patency test:* Partial obstruction 180 mm.–140 mm.; 8 c.c. lipiodol used. Right tube dilated and tubulized. No beading, probably due to peritubal pathology.

[1]From the Adolph Stein Memorial for Research in Roentgenology. Read by title at the Thirteenth Annual Meeting of the Radiological Society of North America, at New Orleans, Nov. 28–Dec. 2, 1927.

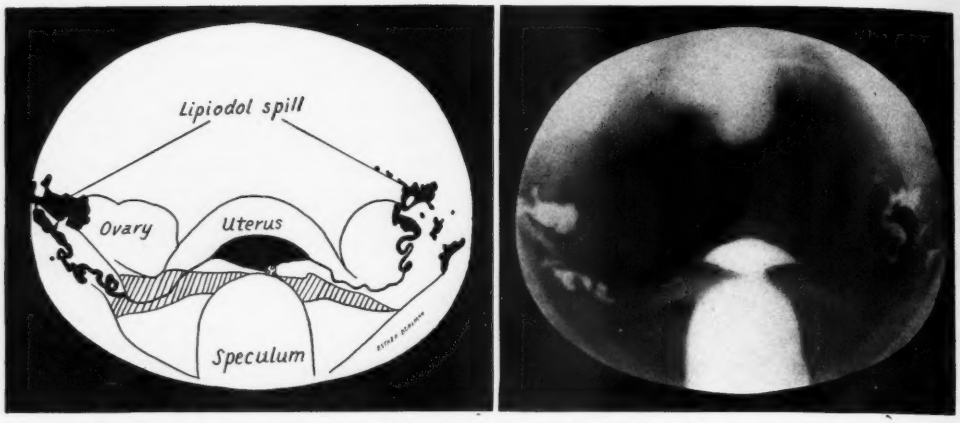

Fig. 2. Sterile 6½ years: post-coital test satisfactory. Tubes patent at 140 mm.–60 mm.; 7 c.c. lipiodol used. Normal genital status, with lipiodol spill at both fimbriated ends.

feel that spasm as exhibited in the uterus and tubal isthmus is comparable to spasm described in the examination of other hollow muscular viscera, namely, a defense reaction against the introduction of a foreign substance or against distention. This phenomenon accounts readily for the numerous cases in which we have found apparent obstruction when gas alone was used for testing tubal patency and in which on repeated tests the tubes were proven to be patent. This is graphically illustrated when iodized oil is utilized, showing one or both tubes patent immediately following the usual patency test with gas in which the tubes appeared obstructed. The converse has also been observed, namely, that after a satisfactory patency test with gas, upon the instillation of iodized oil a typical picture of cornual or isthmic obstruction was obtained in the roentgen films. Again, one tube has appeared filled and the other empty. This also emphasizes the necessity for repeated patency tests when obstruction is encountered,

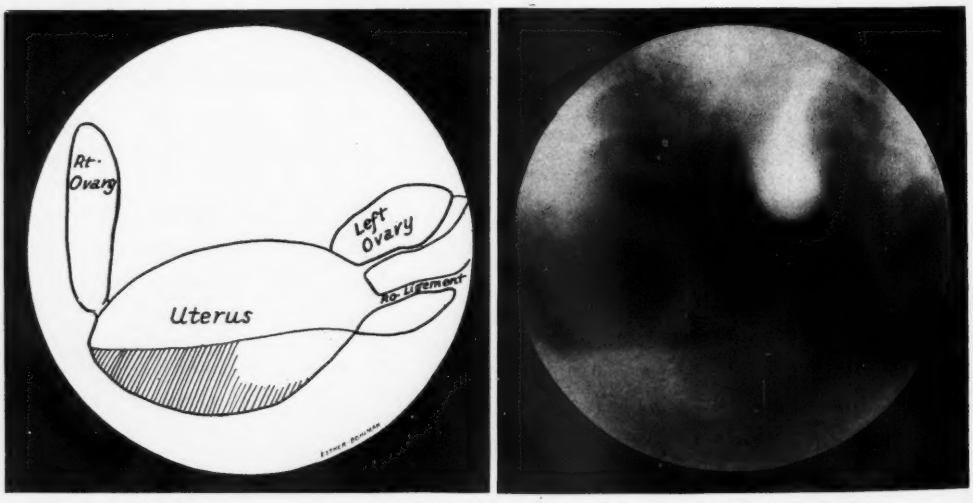

Fig. 3-*A*. Transabdominal pneumoperitoneum; uterus enlarged transversely; ovaries elongated.

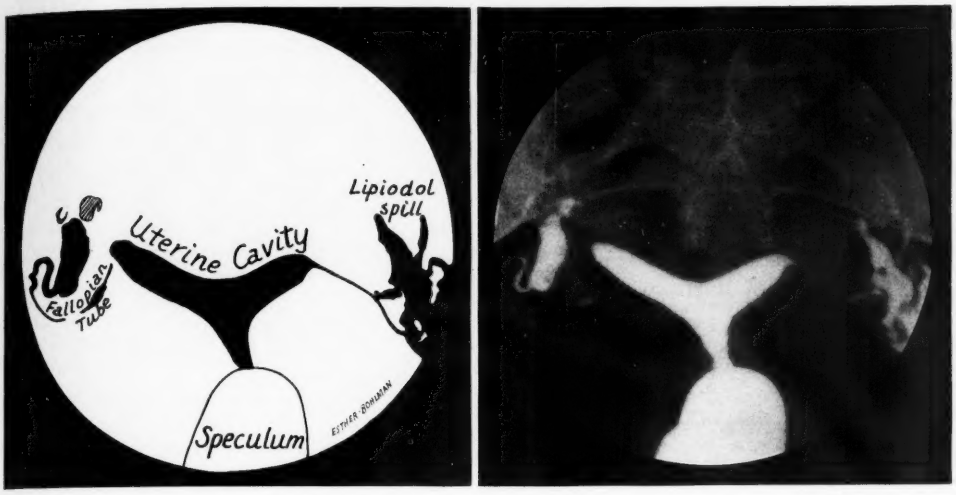

Fig. 3-*B*. Same case as shown in Figure 3-*A*, following lipiodol instillation after gas had been absorbed. Bicornuate uterus. Patent fallopian tubes, with lipiodol spill at both fimbriated ends.

especially in the absence of obvious inflammatory lesions.

Unilateral spasm beginning in the uterine cornu was found to be much more frequent in our studies with the combined method than was recognized with gas alone. The auscultatory findings are not entirely reliable. Occasionally one fails to get the typical râle-like sound over either tubal area and subsequent examination reveals that a pneumoperitoneum has been induced. Again, atypical sounds may be heard which may be confused with those produced by the gas passing through the fallopian tubes and the films reveal that pneumoperitoneum has not been obtained. Furthermore, a typical sound of tubal inflation may be elicited over one tubal area and be absent over the other, and the subsequent films, following lipiodol instillation, may show a filling of the opposite tube only. That the interpretation of spasm in these cases is correct has been checked by means of frequently repeated tests and roentgenograms.

It is not for tubal patency alone that we recommend this method of examination but also for precision in gynecologic diagnosis, and it is for this purpose that we are urging a more extensive use of this method by the gynecologist in co-operation with the roentgenologist. That the method has been tried elsewhere is shown by the recent publication of Jung and Schirmer (*2*), who report 150 cases so studied, with satisfactory results and no ill effects.

Since the note of warning was struck in our contribution of last year we have been on the alert to discover any harmful effects of iodized oil used in this manner and have as yet failed to find any damage to the tubes, nor has there been any evidence of peritoneal irritation. We have also followed a number of patients for a sufficient time after examination to learn how long lipiodol remains in the peritoneal cavity, and have found in a number of such cases, with considerable intraperitoneal "spill," that practically all traces of the iodized oil have disappeared within two weeks. This is in direct contrast to the introduction of iodized oil into the lungs, and into the neural canal, in which cavities traces of the opaque

medium have been found months after its introduction.

As a result of our accumulated experience we feel more than ever that this combined method of examination is one of distinct merit, which often elicits information of the utmost value, not obtainable by other methods of diagnosis. The use of iodized oil logically supplements the patency test as usually performed, and the roentgenogram can be used to depict and graphically illustrate the status of the uterine cavity and tubal lumena. If the visceral contours are to be shown on the film as well, a larger quantity of gas than is usually employed in the patency test must be used (about 1 liter).

The maximum information as to the genital status, short of surgical exploration, may be obtained by the combined method of pneumoperitoneum and iodized oil instillation.

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FRACTURES OF THE PELVIS[1]

By W. H. GILMORE, M.D., CHICAGO

UNTIL early in the twentieth century, the chief cause for fractures of the pelvis was thought to be falls from buildings, scaffolding, trestles, etc., and it was not until the development of the coal mining industry and of automobile accidents that this injury became particularly common.

Before the days of the Bucky diaphragm real diagnostic films of the pelvis were comparatively rare and only the gross lesions in this region were interpreted.

The physical findings are very indefinite even at the time of injury and are of little value three to six months after the trauma has occurred.

In this series of cases the peculiar conditions found in the mining industry in the soft coal region are responsible for the rather unusual traumas. To understand the various applications of force with which we have to contend, the conditions under which the coal miners in the large mines in Southern Illinois work may be briefly described as follows:

All the coal mines in this State, except the so-called "strip mines," are shaft operations. A shaft is sunk to the level of the vein of coal which is to be mined, which in Franklin and Williamson counties lies 500 to 600 feet below the surface, with the vein of coal itself running six to eleven feet. From the bottom of this shaft so-called "main entries" are driven in various directions—usually north, south, east, and west —and from these main entries cross-entries are cut. Opening off the cross-entries are the rooms in which the actual coal mining process takes place. From the bottom of the shaft, extending in various directions in the entries, are railway tracks, on which the trains of coal cars are hauled from the distant parts of the mine to the bottom of the hoisting shaft. Under the Illinois law there must be two and one-half feet on one side of these tracks, without any specified distance on the other, and it is on this other, or off-side, that most of the so-called "squeeze accidents" occur. In mining parlance the man is caught between "the car and the rib," the "rib" meaning the mine wall on this off-side. Other sources of the "squeeze" are the catching of men between the cars and the "face," the "face" meaning the end of an entry, and between cars. Another important cause is the fall of coal, or rock, from the roof. These accidents are brought about by the desire of the men to get out as much coal as possible before setting props, and carelessness on the part of the inspectors in marking off dangerous territory. Occasionally the fall occurs without warning. In this particular type of accident the individual is first knocked down and then covered with tons—few or many—of coal, rock, or slate. All sorts of forces are applied and the men in the coal country have a stock saying that "when coal falls all bets are off," meaning that anything may happen. The trauma extends all the way from a mere shaking up to a completely crushed body—and death.

In this demonstration I shall deal only with the trauma which has taken place in the pelvis proper. Some of these cases have sustained fractures of the transverse processes, and a few have crushed bodies of the various lumbar vertebræ.

In the so-called "squeeze accidents" the force is exerted anterior-posterior, posterior-anterior, or laterally, and it depends upon the direction of this force as to what

[1]Read before the Radiological Society of North America, at the Fourteenth Annual Meeting, at Chicago, Dec. 3–7, 1928.

Fig. 1. Case 1, four months after injury.

Fig. 2. Case 1, two years after injury.

part of the bony pelvis suffers. In the anterior-posterior direction the trauma is confined largely to the rami and the sacrum, while laterally not only the rami but the inner surface of the acetabulum and the ala of the ilium may be involved. In one series of cases the force of the trauma has evidently been directed over the greater trochanter, with the result of this force shown on the internal surface. When the man has been caught between cars and rib, and rolled, we get a combination of forces applied in all directions, and the resulting trauma resembles somewhat that caused by a coal or rock fall.

The physical examination in practically all these cases was made by Dr. J. B. Moore, of Benton, Illinois.

Case 1.—E. P., age 25, injured January 17, 1925. The first examination was made April 6, 1925, about four months after the injury (Fig. 1). This individual was caught between a car and the rib, and rolled. There are fractures of all four rami and a fracture in the lower angle of the right sacro-iliac extending obliquely upward through the body of the sacrum. The only physical evidence reported was some prominence in the right sacral region. The man returned to work in about sixteen months, but his earnings did not become normal until after settlement of some $700 in the Fall of 1927. Figure 2 shows the end-result of the trauma, this film having been made two years and ten days after the injury.

Case 2.—L. T., age 23, injured August 23, 1923, by being squeezed between car and rib. Returned to work December 26, 1923, after about sixteen weeks. Figure 3 was made on September 11, 1924, and shows the condition of the pelvis at that time. There have been comminuted fractures of the ala of the left ilium, of the left sacro-iliac, and of both rami on the left side. His earnings before the injury were $6.71 a day and after his return to work they were $5.95, which showed little change until settlement on December 6, 1924, for $612.50, when his wages returned to normal. Physical examination on September 11, 1924, showed some atrophy in the left buttock,

Fig. 3. Case 2, thirteen months after injury.

Fig. 4. Case 3, twelve years after injury.

the patient protecting the left leg in walking.

Case 3.—S. G., age 35. This case is one in which the possibility of complete recovery after severe trauma in the pelvis, lumbar spine, and soft parts has taken place is demonstrated. This individual was injured in 1914 and was a patient of Dr. J. B. Moore, then surgeon for the Bell & Zoller Coal Co., of Ziegler, Ill. His injury was caused by coal fall. At that time, besides the bone pathology present, the patient had a rupture of the bladder and laceration of the urethra, with extravasation of urine into the perineum. He was in the hospital for some eight or ten months.

On November 10, 1926, I had the opportunity of determining his condition (Fig. 4). He was a well nourished, apparently healthy man, who appeared to be about 45 years of age. He walked with a hardly discernible limp. There had been comminuted fractures of all four rami, complete obliteration of both sacro-iliacs, involvement of the left half of the body of the fifth lumbar vertebra and sacrum, and the crest of the ilium on the left side. In addition, there has been complete bridging along the sacral spinous ligament on the left side and a small hook-shaped area of calcification in the origin of the corresponding ligament on the right side.

This man told me that for several years he had been loading the "turn," which means all the cars allotted to each miner, which average from 2½ to 3½ tons capacity, and that he could have loaded more if he had had the opportunity. In addition, he is the father of a child now seven years of age. His earnings are approximately ten to twelve dollars a day each day the mine works.

A few years ago it would have been impossible not to have felt that the man had some serious permanent disability, and this case goes a long way toward proving my contention that permanent disability resulting from pelvic trauma is very, very rare.

Case 4.—L. G., age 30, injured by coal fall on January 12, 1925, examination made the following November (Fig. 5).

There was no change after this examination until settlement was made. The

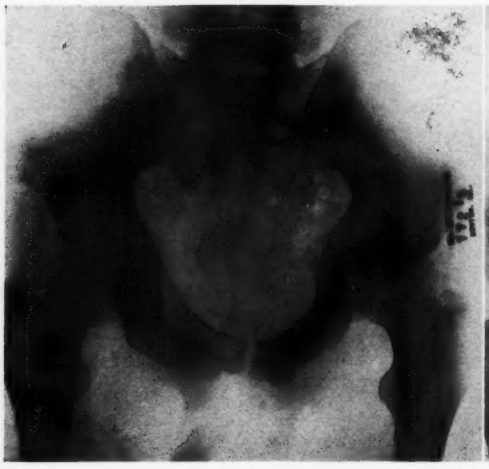

Fig. 5. Case 4, eleven months after injury.

Fig. 6. Case 5, sixteen months after injury.

man complained of pain in the perineum and lumbar region. The only trauma this individual sustained was a slightly comminuted fracture of the left inferior ramus. He was away from work for twenty-four weeks and one day and was paid $286.25 for temporary disability and $1,041.21 for partial permanent disability. I quote from the answer of the company to my request for information on this individual: "At the time of injury he was employed as loading machine man at $10.71 per day. After returning to work he loaded coal by hand and for the last year has averaged $8.35 per day, which is a fair average for coal loaders. Taking into consideration the class of work he was doing at the time of injury and the work he is doing now, it is only fair to assume that his earnings after the injury compare favorably with his earnings prior to injury. This man was not fair, that is, we do not believe he put forth every effort to work. He had in mind a great amount of money as a final settlement and for that reason retarded his earning power. Immediately after settlement was made on December 15, 1925, his earnings increased steadily."

Case 5.—J. K., age 52, injured by a rock fall February 25, 1925. This examination was made sixteen months later (Fig. 6). Complained of distress in the right ilium, right flank, and right side of the sacrum. Physical examination showed some irregularity in the crest of the right ilium, fullness between the crest and the greater trochanter, with the crest apparently displaced inward, and one-half inch shortening in the right leg. There was a rupture of the bladder and laceration of the urethra, which were healed at the time of this examination.

X-ray examination showed crushing fracture of the ala of the right ilium, oblique fractures of both rami on the right side, with involvement of the left pubic bone, and obliteration of detail in the symphysis.

This man was unable to work until final settlement for $1,200 was made April 20, 1927. A six months' strike followed this settlement. He returned to work on October 7, 1927, and has worked every day the mine has operated since.

Case 6.—V. S., age 18, caught between car and rib, injured April 11, 1926. The first examination was made June 1, 1926. The patient complained of pain in the in-

guinal region and in the left hip. Physical examination showed a slight limp in the left leg, but was otherwise negative. X-ray examination (Fig. 7) showed oblique fractures of both rami on the left side, with some involvement of the left sacro-iliac. This individual was away from work for fourteen weeks and regained his average daily earning power within two months after returning to work. Final settlement was for $400.

Case 7.—A. B., age 36, injured by a fall of coal January 8, 1926. This examination (Fig. 8), the final one, was made April 19, 1927. At the first examination, on November 12, 1926, the man complained of pain all over the pubis and in the sacral region. At that time, approximately eleven months after injury, there were no physical signs of consequence. X-ray examination showed comminuted oblique fractures of both rami on the left side and an oblique fracture of the upper half of the sacrum on the same side.

At the time of this examination this individual had not returned to work nor did he go back to the mines. He was a "farmer miner," working his farm until Fall and then going to the mine for the winter work. When the case first came up for settlement the man demanded "total disability," with pension for life, which was denied. After the six months' strike of 1927, this case was settled for $750, temporary compensation amounting to $596.32 having already been paid. He did not return to mining and is now living on his farm in Southern Illinois. Figure 9 shows the lumbar spine of this same individual. The fractures of the transverse processes, three on the right and one on the left side, were caused by the same accident.

Case 8.—S. A., age 40, injured by a coal fall. Figure 10 was made one year after injury. In this case we see a trauma following coal fall, the main force having been applied to the rami and body of the pubis. The fracture through the upper part of the pubis on the right side, with a second through the ala of the right ilium, has allowed some upward displacement of that side of the pelvis, in addition to which we have well healed fractures of the three other rami. This individual returned to work about fifteen months after the injury, having made a settlement for fifty-nine weeks partial disability. For about five months he received $7.50 a day, which was his wage before the injury, after which he left the mine and no further information was obtainable.

Fig. 7. Case 6, one year after injury.

Case 9.—O. M., age 23, injured July 6, 1925, by coal fall. Figure 11 was made about eleven months after the injury. The patient complained of pain in the left sacro-iliac in the supine position, with no complaint of pain in the region of the pubis. Physical examination showed nothing of any consequence except that the left side of the pubis appeared a little high. Here we see

obliteration of detail in both sacro-iliacs and a slightly overlapping fracture, extending upward and outward through the ala of the left ilium. This fracture, together with tearing of the pubic ligaments, has allowed this marked upward displacement of the left pubis and left side of the pelvis.

This case was settled for approximately $1,072, as the applicant did not claim total disability. The man did not return to coal mining: he is a talented musician and is now travelling with an orchestra. Once was enough.

Fig. 8. Case 7, fifteen months after injury.

Fig. 9. Case 7.

Case 10.—W. F., age 31, injured October 3, 1925, by rock fall. He was examined June 18, 1926 (Fig. 12). The force was

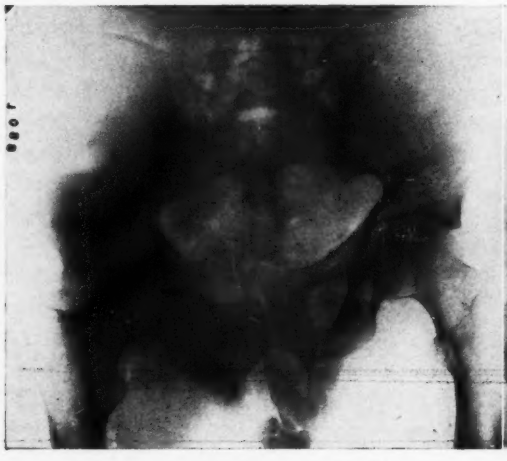

Fig. 10. Case 8, one year after injury.

Fig. 11. Case 9, eleven months after injury.

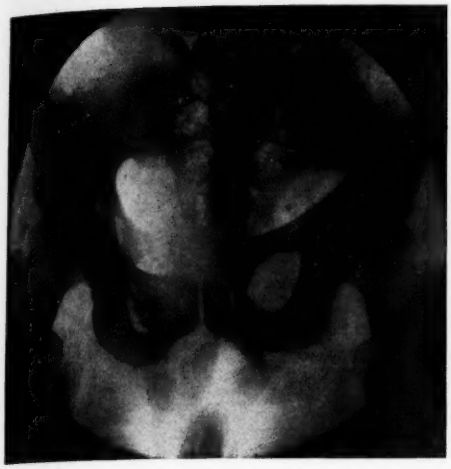

Fig. 12. Case 10, eight months after injury.

Fig. 13. Case 11, ten months after injury.

applied approximately as in the last case, except with more trauma to the left pubic bone. There is involvement of the left sacro-iliac and ala of the left ilium, together with an oblique fracture through the body of the left pubis and all four rami. The physical examination was of no importance. The patient complained of pain in the left upper buttock and sacral back, and stated that lifting caused pain in the left testicle.

The case was settled in the Fall of 1927 for approximately $1,250. This individual was another so-called "farmer miner." He did not return to work after settlement, but confined himself to his farm work.

Case 11.—G. M., age 33, injured January 27, 1926, crushed between a car and the rib. Examination (Fig. 13) was made November 2, 1926, showing the end-result. This is the first of a short series of crushing injuries in which the main force has been applied over the greater trochanter.

Physical examination at the time of the X-ray study showed some slight prominence of the right sacro-iliac, but was otherwise negative. The patient complained of some pain through the pelvis and right side of the perineum.

This man was away from work for twenty-seven weeks and the case was settled for $650. At the time of injury he was earning $12 a day as a gang worker, and on April 1, 1928, $8.82 a day loading alone, which compares very favorably with the wages of a gang worker. It took him approximately six months to return to his former earning capacity.

Case 12.—J. R., age 35, injured November 30, 1923, caught laterally between cars. This examination (Fig. 14) shows the final results as of September 17, 1924. There were fractures of all four rami, with the internal surface of the acetabulum rather prominent, this being slightly more noticeable than in Case 11. The patient complained of pain in the right buttock and perineum, without any definite physical signs. He returned to work shortly after this examination and earned slightly decreased wages until final settlement January 25, 1925, when his earnings immediately became normal.

Case 13.—E. S., age 18, injured August

Fig. 14. Case 12, ten months after injury.

Fig. 15. Case 13, eleven months after injury.

25, 1923, squeezed between a mule and a car. This final examination (Fig. 15) was made on July 16, 1924. The man was away from work for twenty weeks, returning on January 15, 1924. He complained of pain in the buttock and right side of the sacrum, and in the lower portion of the sacro-iliacs when stooping. Physical examination disclosed an apparent defect in the crest of the right ilium, with the right leg three-quarters of an inch short. There was a fracture in the right sacro-iliac, with an increase in the extent of the pathology on the inner side of the acetabulum, as shown in the last two cases. This individual also had a fracture of the inferior ramus on the right side. He was working as a driver at the time of injury, earning $7.50 a day. At

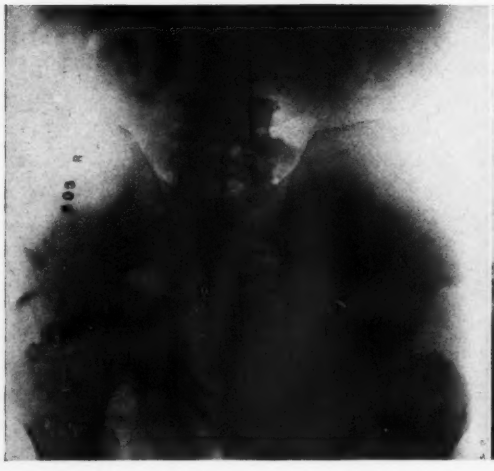

Fig. 16. Case 14, nine months after injury.

Fig. 17. Case 15, two years after injury.

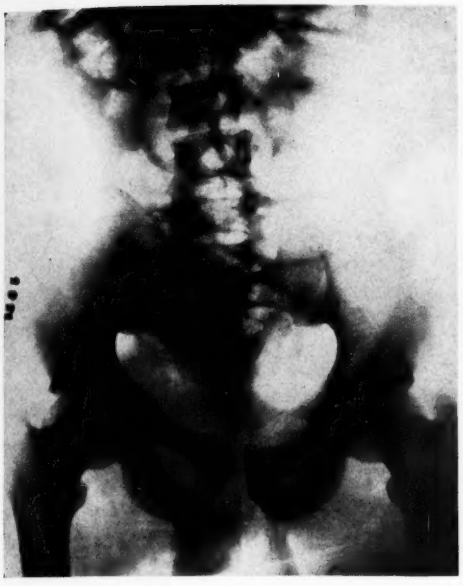

Fig. 18. Case 16, day of injury.

the hearing before the Arbitrator he was awarded some $1,500, or about 65 per cent loss of the right leg. He returned to work at the same employment after final settlement at the same wage and worked the full working time of the mine.

Case 14.—J. J., a man about 50 years old, was injured on August 31, 1920, by fall of coal, and the examination (Fig. 16) was made on May 2, 1921.

The data on physical examination were unobtainable and the man died from pneumonia about one year after this examination, without having returned to work.

This case demonstrates the effect of the same sort of force when carried to what seems an almost impossible degree. The head of the femur is driven entirely through the ilium, carrying the splintered acetabulum with it.

Case 15.—W. D., age 54, injured September 12, 1923, by rock fall, examination being made on September 19, 1925 (Fig. 17). This is another demonstration of the same sort of force, carried still farther, together with fractures of all four rami and the body of the pubis on the right side. This man complained of pain in the sacral region on the left side, with dull aching in the abdomen and popliteal space. Physical examination showed the crest of the left ilium higher than the right, prominence of the left sacro-iliac, some atrophy in the left hip, and the leg to be about one inch short when measurement was taken from the sternal notch. The man was paid $2,475 partial, $1,100 final, settlement.

Fig. 19. Case 16, eight months after injury.

Case 16.—S. L., age 22, injured March 28, 1922, by coal fall. In this particular case I saw the patient at intervals from the time he was injured until the day of final settlement, and also had the unusual opportunity of observing him some four years after he had returned to work.

The first X-ray examination (Fig. 18) shows three fractured transverse processes on the left side, an oblique fracture of the superior ramus on the same side, and a crushing fracture through the lower half of the right sacro-iliac. There is also a comminuted fracture of the right pubic bone and some separation in the symphysis. The next film (Fig. 19) was made some eight months after injury and five months after the patient had left the hospital. Note the

Fig. 20. Case 16, five years after injury.

marked body list which he had developed, with apparent upward displacement of the right half of the sacrum and new bone formation in the symphysis.

This case was settled for approximately $1,650 very shortly after this examination was made. After settlement was made he refused to go through with his agreement and the case was not finally disposed of for some two or three months, when the original offer was accepted. On January 17, 1927, opportunity was offered for another examination. At this time his mother was in Dr. Moore's private hospital in Benton and he was there as a visitor. It was suggested that he allow me to make another examination to see what his condition was then. He was rather loth to do so, and remarked that it was of no advantage to him and if we wanted to know he could see no reason why we should not pay him for the privilege of making the investigation. However, he was finally induced to submit, with the result as shown in Figure 20.

Fig. 21. Case 17, one year after injury.

The bad body list has largely disappeared and we see complete union, with a large amount of new bone formation in the pelvis and sacro-iliac. The union in the fractures of the transverse processes is not so dense, and there is practically no new bone in the third. At the time of this observation the man told me that he was working every day, without any pain of any sort except that he was sometimes a little sore in changeable weather. I think I shall never forget the patient's appearance at the time settlement was made. He was walking on a crutch and cane and was certain that he was "ruined for life." Truly, the working of a "financial plaster" is wonderful!

Case 17.—This injury resulted from the application of another sort of force, and was not sustained in a coal mine accident. The individual is a woman about 30 years of age, who was injured in a cyclone in Southern Illinois March 18, 1925. Examination (Fig. 21) was made March 18, 1926. This case is of peculiar interest, showing a crushing fracture of the left sacro-iliac, with the ilium displaced upward approximately one-third the width of the articulation. I have never seen this particular type of trauma among some 2,500 spines and

pelves which I have had occasion to examine as due to coal mine injuries.

It was my belief for several years after entering this field that cases of severe pelvic trauma, such as I have shown here, would justify the opinion that there would be some permanent disability. However, after having seen case after case, from the time of injury until the return to work, and having ascertained the time necessary for such an individual to return to his normal wage, I think that any case of pelvic trauma which leaves any permanent disability, after an honest effort on the part of the injured person, is rare indeed. The time of rehabilitation varies, of course, but if the injured individual is earnest in his efforts, a period of from six to twelve months is ample for a serviceable restoration.

DISCUSSION OF PAPER BY DR. GILMORE

Dr. E. S. Blaine (Chicago): The two papers[1] that I am to discuss have been grouped together, although they concern two dissimilar subjects. One deals with cases of known injury while the other is one in which we have no definite history of injury in the cases that have been presented. Therefore, my discussion necessarily will be in two parts.

In Dr. Gilmore's very interesting presentation of an extraordinarily large number of pelvic fractures, one is struck with the terrific amount of deformity that can happen in a pelvis and still not incapacitate the individual. It is surprising in some of these cases that the injured can recover, with full restoration of the use of the bones and full recovery of his earning capacity in some of the cases. Those of us who come in contact with medico-legal work are impressed with the amount of deformity that is evident in some cases on X-ray films and the very slight amount of apparent deformity, sometimes none at all, when one makes a physical examination of the patient. As Dr. Gilmore has said in describing the complete recovery of the majority of his cases, immediately after a money settlement of one or two thousand dollars—quite a large sum of money for this type of individual to get all at once, notwithstanding a wage of as much as eight to fifteen dollars a day—they quickly recover from their disabilities and go back to work and show no loss of earning capacity. The degree of deformity, as one sees it on the X-ray films, should not be the criterion on which to estimate the probable disability that will result. One will err in a great majority of cases if he bases his estimate on visual deformity in the form of X-ray shadows.

It is my opinion that we should use a great deal of caution in attempting to make a percentage estimate of probable disability on the X-ray findings alone. It is well known that some lawyers, representing claimants for damages against large business organizations, will harass the X-ray expert on the witness stand who tries to be honest in his interpretation of the X-ray film, and will require him to answer questions by "yes" or "no" in cases when a fair answer cannot be given without qualifications. I try to interpret such films without bias to either litigant, but have some difficulty when confronted with films that are not correctly made or which do not fully represent the condition present. This applies particularly to pelvic cases, notably concerning the lumbo-sacro-iliac structures. I have encountered cases in which a seemingly slight injury, such as a fracture of a transverse process of a lumbar vertebra, caused an apparently greater interference with recovery of earning power than badly deforming injuries of the pelvic girdle itself. Thus we have a very delicate situation, if the question of disability is to be decided on the X-ray evidence alone. In

[1] "Intrapelvic Protrusion of the Acetabulum," by Howard P. Doub, M.D., Henry Ford Hospital, Detroit, will be published in an early issue of Radiology.

some cases, knowledge on the part of the individual of the amount of deformity shown by the X-ray examination frequently influences his actions until a cash settlement is made, after which he quickly recovers from his injury. The less such an individual knows about what the X-ray findings are, the better it is for all concerned—not only the defendant but also the plaintiff himself, because such knowledge frequently generates ideas that the individual is very much more injured than is actually the case.

A few days ago in one of the local courts there occurred an incident in which X-ray films of an injured foot played a part. The films showed a transverse fracture of the base of one of the metatarsal bones. It was a simple fracture with no appreciable amount of deformity, so that the presence of the fracture could easily be overlooked; yet a physician, a man who has qualified as an X-ray expert and who has specialized for twenty-five years in industrial surgery, testified that this film revealed a disabling injury—that the claimant was permanently incapacitated. The X-ray film was made a year after the injury and clearly showed a very good and not excessive callus, with a deformity so slight that it could hardly be seen. This film also showed certain congenital variations, namely, an os peroneum and an os trigonum. The so-called X-ray expert testified that these were the result of the injury claimed and constituted permanent injuries. What could be more unfair and unjust? This is an example of some of the testimony in our courts where misinterpretation of X-ray films is all too frequent.

Sacro-iliac joint injuries in these pelvic cases are very important. So-called sacro-iliac slip is a lesion that, according to some, never exists. Some roentgenologists of large experience claim to have never seen such a case. I refer to true subluxation but not dislocation of the joint.

Several of Dr. Gilmore's illustrations show actual dislocations so obvious that they cannot be subjected to debate. In these dislocations the ilium is entirely out of normal relation with the articular surface of the sacrum. Sacro-iliac slip, if it exists, is extremely difficult to demonstrate roentgenologically and therefore is the source of considerable profit on the part of some lawyers. In the presence of slight variations of alignment of the iliac bone with the sacrum, one should be very careful in diagnosing a sacro-iliac slip. Asymmetry of pelvic bone development in healthy individuals who have not been injured is not an infrequent finding. Around the lumbo-sacro-iliac region there is considerable variation, due to congenital development, familiar to all engaged in X-ray work, and yet many such a variation is termed "traumatic lesion." Most often such diagnoses are made on single or so-called flat X-ray films, without the aid of lateral projections or stereoscopy.

Dr. M. L. Harris (Chicago): The paper on fractures of the pelvis has brought to our attention two very important points. The first of these is that fractures of the pelvis are analogous to fractures of the skull, and that the seriousness of the injury depends not on the bone condition but upon the damage done to the contents of the cavity. We may have the most extensive fractures of the skull that are not serious, provided no damage has been done to the contents of the cranium. It is the same in fractures of the pelvis. If the contents of the pelvis are uninjured, the case as a rule has very little seriousness attached to it.

The next point is one which has already been emphasized, that the appearance of the bones, as shown by the X-ray plate, bears no relation to the disability of the patient. That is of great importance, particularly from a medico-legal standpoint, and of importance in all compensation cases that come before industrial boards. It is a shame that

men with no experience in X-rays, with no experience in interpreting X-ray findings, with no clinical experience in treating fractures or handling cases of fractures of the pelvis, will go on the stand and testify that because the X-ray examination shows deformity of the pelvis, there must be and is total permanent disability of the patient. There is nothing more erroneous, as has been shown here. This is the only paper, so far as I know, in which the author has been able to report the facts ascertained by following the cases, both clinically and by X-ray examination, to final settlement and the return of the individual to his former occupation. Dr. Gilmore's experience demonstrates very conclusively that the X-ray findings are no guide whatever in determining the question of disability.

Dr. L. T. LeWald (New York): I want to pay my respects to Dr. Gilmore for his very careful series of cases, with the follow-up records, and I hope that Radiology will publish this article with the illustrations, so that we can all have them for reference. Dr. Gilmore's analysis and estimate of the amount of damages awarded in these cases by compensation commissions will be a guide to similar cases in other localities, and for that reason the paper, to me, is of great value.

These cases are of such importance that I do not wish to disagree with Dr. Harris except in the way in which he expressed his opinion in regard to the evaluation of the X-ray findings. What I would like to state is that the value of the X-ray findings is very important in determining the amount of disability or lack of disability, if one, as Dr. Harris himself states, takes into account the clinical findings in addition to the X-ray findings.

Now we had a case like one of these in which there was a deformity of the pelvis in a woman who had been run over by an automobile, and it was stated that she was unable to walk. Fortunately the defense were able, unbeknown to her, to obtain a moving picture showing her walking. I was called in, under most remarkable circumstances, as a *neutral X-ray expert* by the judge, and it was a very simple matter for me to express an independent opinion that there was no reason, from the X-ray findings, why that woman could not walk, and the case was readily settled for a nominal sum.

In women, the deformity of the pelvis does bring up another factor, as was done in the case which I have cited: that is, the question of childbirth through a deformed pelvis.

THE RELATIONSHIP OF GASTRIC ULCER TO GASTRIC CARCINOMA

A CASE IN POINT

By MERLE R. HOON, M.D., and JOHN DAY GARVIN, M.D., PITTSBURGH

REGARDING the malignant possibilities of gastric ulcer, opinion is diverse and discussion is rife. Some are of the feeling that the cancer-ulcer relationship has been overstressed and place little credence in it; they are inclined to consider an ulcer of the stomach almost as innocuous, from a malignant standpoint, as one in the duodenum, and so entitled to the same conservative therapeutic measures (1). Others feel that the causal relation of ulcer to cancer in the stomach has not been stressed sufficiently (2), and do not view with equanimity the presence of an intragastric ulceration; they regard it as suspicious of malignant potentialities until proven innocent thereof (3). They, therefore, urge surgical intervention.

"Does carcinoma develop in chronic gastric ulcer?" This question, MacCarty says (4), cannot be definitely answered because there are no positive or negative facts regarding development visible in the study of simple or carcinomatous gastric ulcers. No one has yet, experimentally, produced a chronic gastric ulcer and then produced a carcinoma in that experimental ulcer. "What percentage of gastric ulcers become carcinomatous?" cannot be answered, he says further, by virtue of the fact that it cannot be shown positively that carcinoma develops on ulcer.

The case we are submitting brings out, rather strikingly, the several angles of the ulcer-cancer question. It is that of a spinster, age 60, a music teacher, whose chief complaint was loss of weight for three months, with intermittent attacks of "indigestion"—burning pain in the epigastrium —coming on two to three hours after meals,

Fig. 1. "A very small circumscribed lesion fairly high on the lesser curvature, in exactly a saddle position."

Fig. 2. Film taken on the day following Figure 1, for the purpose of confirming diagnosis.

and relieved by food, soda, and soda mint tablets. For the past three months she had been eating less than usual "just because I thought I ought." With this were other complaints of "nervousness," constipation, etc. Physical examination was negative save for a weight of 91½ pounds, which represented a weight loss of 22 pounds in eleven months. Urinalysis was negative and the blood count showed a very slight secondary anemia. Titration of the gastric content following aspiration at the end of one hour, showed a total acidity of 22 and a free hydrochloric of 16, with a total content of 50 c.c. Fluoroscopic and roentgenographic examination of the stomach showed a very small circumscribed lesion fairly high on the lesser curvature, in exactly a saddle position, that is, not on the anterior or posterior wall. We made the diagnosis of gastric ulcer, probably carcinomatous, operability questionable (Fig. 1). In order to check our findings, the patient was again roentgenographed the following day (August 26, 1927) and the diagnosis confirmed (Fig. 2). From a roentgenological standpoint, of course, the possible malignant nature could not be definitely determined. In fact, in view of the small size of the crater and the rather marked prepyloric spasm, as noted also by Moore (5), the indication would be that of a benign lesion. However, because of the relatively low acidity, the weight loss, the age of the patient, and the lessening of definite ulcer symptoms, we considered the lesion as probably a malignant one and rather urged operation. The decision was a rather abrupt and unexpected one for the patient's family, who demurred and requested that we "wait just a little longer and see what happens." At their behest, therefore, and on their responsibility, a medical ulcer regimen was instituted, with a resultant gain in weight of three pounds in three weeks and some abatement of the patient's epigastric distress. On October 12, 1927, however, she reported at our request, and said she "felt worse," and when examined was found to have lost five pounds. At this time fluoroscopic and roentgenographic examination was again done, showing a large perforating lesion on the site of the previous smaller one (Fig.

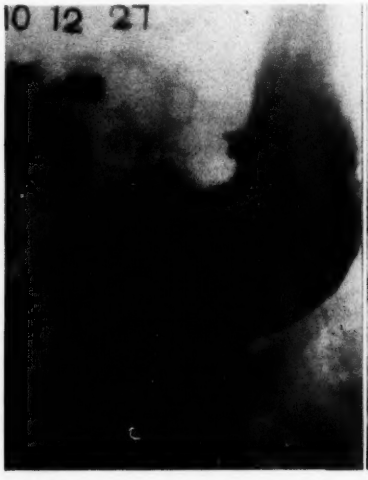

Fig. 3. "A large perforating lesion on the site of the previous smaller one."

Fig. 4. The condition a few days previous to operation.

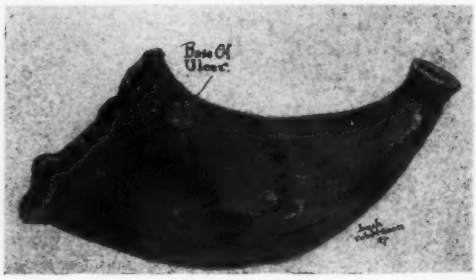

Fig. 5. Posterior aspect of excised portion of stomach, showing where base of ulcer was adherent to and shaved from pancreas.

Fig. 6. Sketch of the lesion from the internal aspect of the stomach.

3). A definite diagnosis of malignancy was then made because of the factors mentioned above plus the extremely rapid growth of the lesion to its present size in less than seven weeks. Surgical intervention again being urged, even more strongly, the family assented, but only after a few days' delay. Figure 4 shows the result of the roentgen examination made a few days before the operation. An apparent increase in size can be noted in this period of eight days.

At operation, October 24, 1927, the lesion was found, as previously described, high on the lesser curvature and attached posteriorly to the pancreas. On examination the liver, pelvis, mesenteric glands, and the glands of the lesser curvature showed no gross evidence of metastasis. Two-thirds of the stomach was excised (Fig. 5), the stump of the duodenum was closed and an anterior Polya anastomosis was done. Grossly, the lesion was a clearly punched-out ulcer and to all appearances was wholly benign. (Figure 6 shows a sketch of the lesion from the internal aspect of the stomach.) Both Dr. Andrew Wallhauser and Dr. Henry M. Ray, of Pittsburgh, on microscopic examination, diagnosed it as definitely malignant. This was confirmed by Broders, of the Mayo Clinic, who diagnosed it as "Grade 4 carcinoma," with no involvement of the glands removed from the lesser curvature. The patient made an uneventful and satisfactory recovery and on a general diet, with practically no restrictions, gained ten pounds in a few weeks. When last seen, on August 22, 1928, she was "feeling fine and eating everything."

COMMENT

The chronic gastric ulcer undergoing carcinomatous degeneration and the ulcerating cancer in its circumscribed or early stage reveal gastric carcinoma in its most hopeful aspect (6). It has not been estimated definitely to what extent gastric ulcer becomes malignant or how frequently a carcinoma shows evidence of a pre-existing benign lesion. "For practical purposes it is sufficient to say that every gastric ulcer should be regarded as a potential carcinoma and that a number of gastric lesions having many of the gross clinical and roentgenological characteristics of ulcer are actually carcinomatous" (6). This very succinctly expresses our attitude on, and the point we wish to emphasize in, the case just cited. It furnishes a most hopeful opportunity for a cure insofar as time and the apparent progress of the disease, alone, are considered. (However, the extremely few cases of "Grade 4 carcinoma" that are able to

avoid recurrence must be borne in mind, as must also the exceedingly rapid growth of the lesion in question. Furthermore, the time that has elapsed since operation[1]—ten months—is too short to permit of optimistic generalizations and conclusions.) We are firmly convinced of the impossibility of differentiating early carcinoma from simple gastric ulcer by "any known means, roentgenoscopy included" (7). Whether the ulcer we are here dealing with was malignant from its inception or whether it represents the development of a carcinoma on an ulcer is of academic rather than practical interest. Too often we fail to differentiate the things which are of purely scientific interest from those which are of practical importance. In this case it was impossible to make a definite differentiation pre-operatively, although we were fairly certain in our conclusions.

We, therefore, submit, in harmony with many others and probably as opposed to an equal number, that all demonstrable intragastric lesions must be regarded with suspicion (3). Once such a finding is encountered, the patient should be kept under the strictest supervision, much more so than that required by a duodenal ulcer, obviously. The results of removal of carcinomas in the early stages, such as this one, are relatively satisfactory. But to secure the benefit of available surgery, all cases of "indigestion" or "dyspepsia" of whatever nature, in the cancer age, should receive exhaustive investigation and be considered of a malignant nature until proven otherwise. Finally, we agree with McVicar and would emphasize his dictum that "the medical management of gastric ulcer must always be undertaken with a forbidding doubt."

[1]Up to Feb. 18, 1929, the excellent condition still persists, sixteen months after operation.

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EDITORIAL

M. J. Hubeny, M.D. . . . . *Editor*

Benjamin H. Orndoff, M.D.
John D. Camp, M.D. } *Associate Editors*

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CHOLECYSTOGRAPHY

Cholecystography is undoubtedly a valuable aid in the study of gall-bladder disease, but it is now apparent that it falls far short of the almost absolute accuracy claimed by some of the original investigators.

This is not surprising when it is recalled that cholecystography is, in fact, a test of the functional activity of the entire biliary tract, rather than a method of studying the anatomical condition of the gall bladder.

If the test were solely dependent upon the anatomical condition of the gall bladder, the same results should follow in each administration of the dye. However, this is by no means the case, and not infrequently a repetition of the test has given directly contradictory results.

A successful gall-bladder visualization rests upon the following six factors: (1) A sufficient concentration of the dye in the blood stream; (2) a liver capable of excreting the dye; (3) patent common and cystic ducts; (4) a gall bladder capable of receiving and discharging the dye; (5) a gall bladder capable of concentrating the dye; (6) a properly functioning sphincter mechanism at the lower end of the common duct. A disturbance in any one of these six factors would result in a partial or complete failure of gall-bladder visualization; yet several of them are entirely independent of the anatomic condition of the gall bladder.

It is apparent that a sufficient concentration of the dye in the blood stream is of prime importance. The intravenous method with known dosage obviously answers the requirement; the oral method as obviously introduces the uncertain factor of intestinal absorption, which in the individual case cannot be dismissed. A failure to visualize after the oral administration, therefore, demands a repetition of the test by the oral, or, preferably, by the intravenous, method before concluding that a disturbance in the biliary system exists.

As the excretion of the dye is dependent upon the functional activity of the liver cells, it is evident that with widespread liver damage partial or complete failure of gall-bladder visualization might result from poor excretion of the dye, even in the presence of a functionally normal gall bladder.

Obstruction in the common or cystic duct will obviously interfere with the excretion of the dye by the liver or with its entrance into the gall bladder.

If the lumen of the gall bladder be filled with stones, polypi, newgrowths and so forth, or if the wall be thickened and inelastic, little or no dye will gain entrance to the gall bladder, and a failure naturally results. Whether or not a normal gall bladder may be filled with concentrated bile at the commencement of the test, so that dye in sufficient concentration to give a normal visualization fails to appear within the gall bladder, seems worthy of consideration.

The concentration of the dye in the gall bladder is essential to a normal test. Presumably this is a function of the wall, but the exact mechanism is as yet unknown.

The factor of the sphincter mechanism at

the lower end of the common duct has not received the attention that it demands in connection with this test. It is established that the lower end of the common duct must be tonically contracted in order that freshly secreted bile may find its way through the cystic duct into the gall bladder. Without this closure of the lower end of the common duct the liver bile flows directly into the duodenum. We accept that the sphincter of Oddi is tonically closed during the interdigestive periods, preventing the passage of bile into the duodenum; but that during the digestive periods, in response to various stimuli, it relaxes, allowing the discharge of bile. As a matter of fact, we know very little of this sphincter mechanism and of its control, yet the accuracy of the test depends upon the proper functioning of this sphincter. Is it not possible that this sphincter relaxes in response to reflex stimuli from the stomach, duodenum, colon, and so forth, and that occasionally, at least, failure of the test results from the faulty functioning of the sphincter, rather than from gall-bladder pathology?

With these points in mind it is evident that due caution must be exercised in interpreting the results of cholecystographic examinations and especially that we must view the findings from the standpoint of the functional activity of the biliary tract, rather than exclusively from the standpoint of the anatomical condition of the gall bladder.

W. W. Boardman, M.D.

ANOTHER SHOWING OF THE CANTI FILM

CHICAGO, APRIL 10

The Chicago Roentgen Society and the Chicago Medical Society, at a joint meeting at the Medical and Dental Arts Building on April 10, are to have an opportunity to see the remarkable Canti film, which was shown twice during the Annual Meeting last December. Many who have already seen this cinematographic demonstration of cell development, activity, and division, together with the effect of radium upon normal and malignant cells, will avail themselves of further opportunity to deepen the impression made by this new method of observation. When it was shown in St. Louis, Dr. Edwin C. Ernst in the course of his introductory and explanatory remarks made use of a figure of speech to illustrate the synchronization of time and the phenomena taking place on the film in saying that it was as if one might witness his son's development from boyhood to manhood, speeded up and condensed to a three-reel film.

LOST SLIDES

Dr. Walter T. Bronson is holding several slides which were left at the Chicago meeting, about the projecting lanterns. If any one has lost any of his slides and has reason to think they may be among these, he might write to Dr. Bronson, Northwestern University Medical School, McKinlock Campus, Chicago, Illinois, describing them so that they may be identified and returned to their owners.

INTERNATIONAL WEEK OF LIGHT THERAPY

Paris, France, July 22 to 27, 1929

Organized by the Institute of Actinology. President: Professor D'Arsonval, member of the Academy of Science and Professor at the College de France.

I. International Congress of Actinology (July 22, 23, 24, 1929). (Official languages: French, English, German, Italian.)

Section A.—Papers on and discussion of the following questions:

1. Selection of a unit of measure for the ultra-violet rays used in medicine.
2. The light treatment of tuberculous peritonitis.
3. The prophylactic value of ultra-violet rays.
4. The treatment of rheumatism by infra-red rays.

Section B.—Communications by members on various subjects of present-day interest.

II. International Exhibit of Apparatus (July 22 to 27, 1929).

Section A.—Instruments for the analysis and measurement of radiation.

Section B.—Ultra-violet, infra-red, and chromotherapeutic lamps.

Section C.—Organization and equipment of light clinics.

Section D.—Electrical sources.

Section E.—Irradiated preparations.

III. Exhibit on the history of light (July 22 to 27, 1929).

Section A.—Light in antiquity. The sun considered as a healing god. Heliotherapy as practised by different peoples. Heliosis and solaria.

Section B.—The modern renaissance of heliotherapy.

Section C.—The creation of photo-therapy, from the apparatus of Finsen to the present lamps.

IV. Lectures on recent progress in the therapeutic application of light by scientists from different countries (July 25 and 26).

V. Demonstrations of experimental technic in physics, physiology, and therapeusis with ultra-violet and infra-red rays, by scientists from different countries (July 26 and 27).

VI. Elementary course in actinology by the director and associates of the Institute of Actinology.

Besides, a program of receptions for members of the Congress and their families is being arranged. This will include:

1. Reception at the City Hall of Paris.
2. Performance at a theater, at which a musical concert with classic compositions on the sun or on light, will be given.
3. Visits to the museums of Paris.
4. An excursion to Fontainebleau.

Steps have been taken to obtain a reduction in railroad fares in certain countries.

DR. SAIDMAN, *Director of the Institute of Actinology.*

DR. DUFESTEL, *Secretary-General of the Congress.*

BOOK REVIEWS

INTERNATIONALE RADIOTHERAPIE. BESPRECHUNGSWERK AUF DEM GEBIETE DER RONTGEN-, CURIE-, LICHT-, U. ELEKTROTHERAPIE. Begrundet und herausgegeben von J. WETTERER (Mannheim) in Gemeinschaft mit F. BARDACHZI (Aussig), D. CHILAIDITI (Konstantinopel), R. GASSUL (Kasan), W. LAHM (Chemnitz), A. H. ROFFO (Buenos Aires), HENRY SCHMITZ (Chicago), F. SLUYS (Brüssel), J. SOLOMON (Paris), M. SPINELLI (Neapel). Band III. Pages 1320, 8vo, with frontispiece of autographed portrait of J. Wetterer. Bound in green linen buckram. Price 64 marks. Published by L. C. Wittich, Darmstadt, Germany, 1928.

This, the third volume of what may well be considered the most valuable international review of radiotherapy, appears to merit all the favorable comment made by your reviewer of the second volume, in RADIOLOGY for April, 1928 (page 360).

Volume III exceeds the previous one in size and contents by 260 pages (25 per cent), and must, therefore, be 25 per cent

more useful and valuable. It has also an additional collaborator in the person of A. H. Roffo, of Buenos Aires.

The general style, make-up, and character of the contents are of the same high quality as were the previous volumes, although, of course, the material is entirely new and different. This might be made somewhat more valuable and useful to American readers by having a more complete review of American radiologic literature.

The fact that this volume contains reviews of the papers and discussions presented at the International Congress at Stockholm should cause it to be more than ever in demand. Consisting as it does of the combined work of so many writers, so finely arranged and edited as to make its contents easily accessible, it is a most valuable book.

I. S. T.

NEUERE ERFAHRUNGEN AUF DEM GEBIET DER MEDIZINISCHEN ELEKTRIZITATSLEHRE MIT AUSSCHLUSS DER RÖNTGENLEHRE (ELEKTROPHYSIK, ELEKTROPHYSIOLOGIE, ELEKTROPATHOLOGIE, ELEKTRODIAGNOSTIK, ELEKTROTHERAPIE). Edited by PROF. DR. MED. LUDWIG MANN (Breslau) and PROF. DR. MED. FRANZ KRAMER (Berlin). Pp. 501, with 258 illustrations. Leipzig: Georg Thieme, 1928.

This book is a supplement to the lexicon on the use of electricity in medicine which appeared in 1909-1911. Fifteen authors have joined forces in order to give a complete up-to-date presentation of the subject. There is an introductory chapter (G. Hoffmann) on the electron, atom, radio-activity, and ionization, followed by a somewhat meager discussion of the electrical apparatus used in medicine (K. Bangert). The next contribution and probably the best in the whole book relates the present status of electrophysiology (W. Steinhausen). Very interesting is the wide use of the electron tube in physiology and the author has been quite instrumental in some pioneer work along these lines. The articles on technic and method of the electrocardiograph and the interpretation of the pathologic electrocardiogram will be welcomed by many readers (H. Schaffer). Of great importance is the chapter on injuries of the organism due to electrical currents, a special subdivision sometimes called electropathology (E. Schilf). The essay dealing with general electrodiagnostic, its application in nerve and muscle diseases, offers much valuable information (F. Kramer).

The therapeutic part is opened by a chapter on general electrotherapeutics (L. Mann), followed by a discussion of franklinization and treatment with high frequency currents (J. Kowarschik), then electrolysis (C. A. Hoffmann). The remainder of the book has been divided among the specialties. The reader finds articles on electrotherapy in nerve and muscle diseases (L. Mann), in internal diseases, particularly those of the heart (F. M. Groedel), the use of electricity in rhinolaryngology (A. Alexander), in otology (W. Klestadt), in ophthalmology (O. Fehr), in skin diseases (C. A. Hoffmann), and in diseases of the joints (L. Mann). The editors state in the preface that gynecology had to be left out because the author of that chapter failed to deliver the manuscript.

E. A. POHLE, M.D., PH.D.

The hypothetical element "coronium," visible in the sun's corona during eclipses, may be identical with the rare gas argon, experiments by Dr. Ira M. Freeman, of the University of Chicago, indicate.—*Science Service.*

ABSTRACTS OF CURRENT LITERATURE

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The Calibration of the Sabouraud-Noire Dosimeter in Roentgen Units and its Usefulness in Practical Dosimetry. H. Th. Schreus. Strahlentherapie, 1928, XXIX, 375.

Comparative measurements with the Sabouraud-Noire Dosimeter, a Hammer and a Kuestner instrument, demonstrate the fact that the calibration of the Sabouraud-Noire Dosimeter in roentgen units is rather difficult. When using the corrective factors for different wave lengths, very high erythema doses are derived if expressed in roentgen units. This is hard to explain in view of the long practical use of the Sabouraud-Noire Dosimeter. Further investigations are important. For practical purposes, it is possible to measure a dose within 15 to 20 per cent.

E. A. POHLE, M.D., PH.D.

The Failure of Cholecystographic Filling in the Presence of Acute Pyloric Pathology. E. H. Skinner, Ira H. Lockwood, and E. R. Deweese. Am. Jour. Roentgenol. and Rad. Ther., April, 1928, XIX, 340.

During the routine use of the Graham gall-bladder test by the oral method the writers found six individuals with normal gall bladders whose Graham reactions, however, were strictly pathological, in each case active ulceration being present at the pyloric end of the stomach or in the first portion of the duodenum. They believe that active pathology with peritoneal irritation may interfere with the usual reaction of a normal gall bladder, whereas chronic organic pathology without peritoneal irritation will not influence the expected gall-bladder response.

J. E. HABBE, M.D.

Diverticulosis of the Vermiform Appendix. George T. Pack and Isabel Scharnagel. Am. Jour. Surg., October, 1928, V, 369.

The literature is reviewed in this article and a case is described. There are several illustrations of a case of this condition.

H. P. DOUB, M.D.

Diverticulosis of the Urinary Bladder. E. J. Boardman. Can. Med. Assn. Jour., June, 1928, XVIII, 661.

This condition is fairly common to the urologist, and is of great importance from the standpoint of surgery on the prostate. The regularity with which it forms a part of the clinical picture in prostatic obstruction indicates a possible relation between the two. The increasing pressure consequent upon the bladder obstruction is likely to produce weakness in the bladder wall, which finally gives way in spots and initiates diverticula.

If the presence of a diverticulum is not recognized before operation there is small chance of it being revealed by a careful search during the operation. Even when the approximate location has been designated by cystoscope and cystogram, the orifice may be difficult to locate through the suprapubic incision. Failure to find and remove the sac will lead to future intractable cystitis, through the entrance

of infection into the diverticulum following the operation, since all bladders become infected during the prostatic operation.

L. J. CARTER, M.D.

The Treatment of Psoriasis with Intravenous Trypaflavine Injections and Quartz Light. M. Oppenheim. Strahlentherapie, 1928, XXIX, 268.

Patients suffering from psoriasis were sensitized to ultra-violet rays by injecting trypaflavine intravenously. If 5 c.c. of a 1 per cent solution were tolerated, 10 c.c. were given, three times a week. This was supplemented by daily baths with oil soap, ultra-violet exposure, and application of 5 per cent boric acid vaseline. The results were encouraging.

E. A. POHLE, M.D., PH.D.

Biologie des Uraniums (Biology of Uranium). Julius Stoklasa and Jos. Penkava, et al. Biochem. Ztschr., 1928, Band 194 (1-3), 15-77.

In this detailed research the action of the uranyl ion upon the metabolism of bacteria, the germination of seeds, the processes of transpiration, the development of plants in culture media and in vegetation vessels was studied, as well as the physiological effects of the different types of uranium rays upon the germinating process and the development of plants. Minute quantities of uranium, from 0.00000-3125 to 0.0000125 gram atoms per liter (2×10^{-7} and 9×10^{-7} millicurie) increase considerably the metabolism of bacteria. Uranium in dilute solutions has a somewhat beneficial effect upon the germinating process of leguminous plants, while solutions of higher concentration (more than 0.005 gram atom per liter) have a depressive effect. The transpiration processes of plants in culture media are increased by uranium. In small quantities, *i.e.*, 0.0014 to 0.0042 gr. uranium per 1000 c.c., uranium has a favorable effect upon the photosynthesis, the assimilation of carbon dioxid, and the formation of new living cells. The assimilation of nitrogen by the roots is also increased. In the dark the same quantities of uranium have a depressive effect upon these processes. Similar favorable effects of uranium upon plants in vegetation vessels were observed.

The experiments proved that the beta and gamma rays of uranium combined, as well as the gamma rays alone, have a depressive effect upon the development of the root and cotyledon of plants. On the other hand, photosynthetic processes are stimulated by the beta and gamma rays. Gamma rays have a stimulating effect in small doses, but suppress the life of the protoplasm in larger doses.

OTTO GLASSER, PH.D.

Post-operative Jejunal Ulcers. Norman M. Allen. Am. Jour. Surg., August, 1928, V, 128.

The author believes that the treatment of choice in marginal ulcer, when the primary operation is gastro-enterostomy, is disconnection of the gastro-enterostomy, resection of the ulcer, repair of the jejunum and stomach providing there is no stenosis of the pylorus. He does not believe it justifiable as a primary procedure to sacrifice a large portion of the stomach for duodenal ulcer. Marginal ulcers occur just as frequently after partial gastrectomy as after gastro-enterostomy and when they occur present a more formidable surgical procedure than when a simple gastro-enterostomy has been performed.

H. P. DOUB, M.D.

Jejunal and Gastro-jejunal Ulcers. Arthur F. Hurst and M. J. Stewart. The Lancet, Oct. 13, 1928, CCXV, 742.

The authors discuss the frequency, etiology, and pathology of stomal ulcer following gastrojejunostomy. They believe that the incidence is much greater than has been shown in previously published surgical reports. An interesting table shown is based on analysis of 131 cases of gastrojejunostomy for simple lesions of the stomach and duodenum coming to autopsy. In a group of 42 cases in this series in which death occurred more than nine months after operation, jejunal ulceration or scarring was found in 22 cases. In all of these cases the gastrojejunostomy had been performed because of duodenal ulcer. The authors do not offer this as a true criterion

of frequency but do state that the incidence is much greater than previous statistics would indicate.

From their autopsy findings the authors feel that a jejunal ulcer rarely heals spontaneously. In the cases which have developed jejunocolic fistula the jejunal ulcer may heal rapidly, probably because of neutralization of gastric acidity by regurgitated colonic contents.

The authors favor a course of medical treatment before operative procedure is undertaken. From a group of 25 cases of gastrojejunal ulcer treated medically, 13 recovered without operative interference. Pathogenesis and the course of gastrojejunal ulcer are discussed at length and many valuable suggestions are offered as regards treatment.

MILTON J. GEYMAN, M.D.

Radium Therapy in Cancer. Editorial in Can. Med. Assn. Jour., September, 1928, XIX, 351.

This is a summary of the conclusions reached at the recent International Conference on Cancer. Emphasis was placed on the value of radium, in comparison with surgery, in the treatment of certain types and at certain stages of cancer. Epitheliomata of the epidermis and of the oral region are specially sensitive, and their cure by radium may now be predicted with confidence. Cancers of the breast and cervix uteri are likewise sensitive to radiation, but treatment of these may be complicated by the degree of extension to deeper structures. On the other hand, rectal cancer is distinctly resistant to radiation, and adenocarcinoma of the uterus, as well as of other glands, is likewise only slightly affected by radium.

Statistics are now available to show that the end-results of radium treatment in the types of cancer mentioned are as favorable as those produced by surgery. The fact that radium has no operative mortality should often turn the decision in its favor.

L. J. CARTER, M.D.

Substances Circulating in the Blood as Cause of Light Dermatoses. Werner Lipschitz. Strahlentherapie, 1928, XXIX, 9.

Porphyrin circulating in the blood may cause death of the organism, if exposed to light. This photodynamic effect can also be induced in a milder way by organic dyes, like eosin. Another interesting reaction due to light is the activation of ergosterol, which is in all probability the main factor in the cure of rickets. This comparison shows that the effect of light can be fatal, while, on the other hand, it is of great therapeutic value. The organic chemistry of these various reactions is set forth in the article.

E. A. POHLE, M.D.

POSITION WANTED—By experienced X-ray technician. Willing to co-operate, capable, pleasing personality. Address A-43, care RADIOLOGY.